Australian e-Health
Research Centre

The Australian e-Health Research Centre

Annual Report 2022–2023

Queensland Government

Traditional Owners Statement

CSIRO acknowledges the Traditional Owners of the lands, seas and waters, of the area that we live and work across Australia. We acknowledge their continuing connection to their culture and pay our respects to their Elders past and present.

CSIRO is honoured to partner and collaborate with Aboriginal and Torres Strait Islander communities across the nation and we acknowledge the contributions of all Aboriginal and Torres Strait Islander people, staff and partners towards our vision for reconciliation.

Important disclaimer

Contents

The Australian e-Health Research Centre

The Australian e-Health Research Centre (AEHRC) is the largest digital health research program in Australia with over 150 scientists and engineers and a further 50 higher degree research students.

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

Established in 2003 with initial funding from the Queensland Department of State Development and CSIRO, the partnership was extended in 2007 for a further five years with funding from CSIRO, Queensland Health and the Department of Employment, Economic Development and Innovation. In 2012 the partnership was extended for a further five years with an additional contribution of $15 million from CSIRO and Queensland Health, supplemented by in-kind contributions from the partners, as well as funding from grants, research consulting and commercialisation. The partnership was extended in 2017 and again in 2022 for an additional five years with a further contribution of $15 million from CSIRO and Queensland Health.

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

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

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

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

The current AEHRC strategy engages the research capability of our five research groups – Health Data Semantics and Interoperability, Health System Analytics, Biomedical Informatics, Transformational Bioinformatics; and Digital Therapeutics and Care – to continue to tackle Australia's healthcare system challenges and expand the impact of our research. The challenges set out in this strategy are to:

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

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

Over half our people are located in the STARS Hospital on the Herston Health Precinct in Brisbane, while in Sydney we have moved 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, but especially within human health and biosecurity programs in CSIRO Health and Biosecurity.

Foreword by the Chair and CEO

During the past year the science and impact from the work of Australian e-Health Research Centre staff has expanded significantly – and we hope that we have captured the energy and significance of these achievements adequately in this 2022–2023 annual report.

Over the past 12 months our work on interoperability has been adopted at a national level with two new collaborations.

In September 2022 the AEHRC joined forces with the Australian Digital Health Agency (the Agency) to further our role in delivering the National Clinical Terminology Service. Under the new partnership, the Agency retains responsibility for governance and the strategic role of end-to-end management, SNOMED CT licensing and the relationship with SNOMED International, while AEHRC will be responsible for delivering the services and functions required to manage the NCTS, as well as content authoring and tooling. As part of the change the AEHRC has had five fabulous staff move from the Agency to CSIRO while several other staff join the team to deliver this important national infrastructure.

Then in the May Federal Budget funding was announced for CSIRO to work with the Department of Health and Aged Care, the Australian Digital Health Agency and HL7 Australia to deliver a two-year FHIR Accelerator to advance interoperability standards in Australia. FHIR accelerators, such as the Argonaut Accelerator in the USA, have been successful in increasing the exchange of information to support patient care. The key to Argonaut's success was in building the community to agree and trial the standards before their adoption. We intend to follow that model. This project is just getting underway – so more on it in next year's report!

Meanwhile the uptake of our interoperability tools – including the licensing of our FHIR terminology server, Ontoserver – internationally continues to grow.

While interoperability was a substantial topic for AEHRC and our partners, there can be no doubt that the past 12 months has seen the start of a sea-change in the adoption of artificial intelligence in healthcare. The launch of the ChatGPT AI in November saw interest in AI around the world move from the technology community into the general community, and health wasn't immune. While large language models (LLMs) such as ChatGPT represent only a small part of the AI ecosystem, they have captured the imagination of future possibilities in AI.

AEHRC scientists and engineers have been using AI technologies to power our research and development over many years, including in the development of new AI technologies, tools, and algorithms. This year our imaging team's algorithm for knee cartilage assessment, developed in collaboration with the University of Queensland, was commercialised globally by Siemens Health. Also on the imaging front, a team of our postdoctoral fellows participated in ImageCLEF – an international challenge to build the best AI system for medical imaging tasks – and won the tuberculosis detection from CT scan task!

We are also contributing to national initiatives in AI, working as part of the Australian Alliance for AI in Healthcare to develop policy recommendations for the adoption of AI in healthcare. Our team also collaborated with the National Disability Insurance Agency, along with disability groups and industry representatives, to develop a framework and roadmap for implementation of AI-enabled assistive technology for disability.

Our AI research also features heavily in the papers we are publishing. A collaboration between our bioinformaticians and health informaticians resulted in a paper accepted by *Nature Biotechnology* on using AI to query across genomic and medical data, including whole genome sequences, while we also published a paper about predicting patient deterioration using AI algorithms in *Nature Scientific Reports*. A full list of our publications is presented at the end of this report.

Our teams contribute to many national and international studies. As part of the Australian Dementia Network, we have supported the collection of data on 1100 participants across 5 states, with MRI and PET imaging biomarkers calculated by our technology. Our image analysis technology has also demonstrated the value of MRI scans in providing measures to accurately predict two-year outcomes for babies born very prematurely.

Overall, we partner in over 30 NHMRC and MRFF grants, often providing key technology to support trials and studies of new technology to solve difficult medical, clinical, and health service challenges.

The AEHRC continues to contribute to national programs through CSIRO. As part our support for CSIRO's Minimising Antimicrobial Resistance Mission we delivered a Department of Health and Aged Care supported pilot to integrate our HOTspots surveillance and response technology into the Antimicrobial Usage and Resistance in Australia (AURA) program part of Australia's National AMR Strategy.

Also on the national stage we worked with Healthdirect Australia to evaluate the Living with COVID (LwC) program, demonstrating that the program supported patient care through efficient triage and by connecting consumers to primary care enabling early intervention to enhance health outcomes.

Furthermore, we continue to work widely with Queensland Health. Our M♡THer platform for the management of gestational diabetes has now benefited >6000 women around Queensland. We have also started a new project with funding from the Emergency Medicine Foundation to undertake a comprehensive state-wide study in patient flow.

We've advanced our ongoing Indigenous health research with projects in Queensland and around Australia. This year two PhD students in our Indigenous Health team had their PhDs confirmed – congratulations to Georgina and Andrew. Andrew has taken up a postdoctoral fellow to continue his research and is currently one of CSIRO's few Indigenous Postdoctoral Fellows.

The 2022–23 AEHRC Annual Report provides an overview of our research – including our research groups, platform technologies, project reports and project updates. The report this year highlights many of our successes and ongoing projects – demonstrating our central role in Australia's transition to a digitally enabled healthcare system.

Richard Royle
Chair
The AEHRC

David Hansen
Chief Executive Officer
The AEHRC

Board of Directors

Richard Royle

Chair, the Australian e-Health Research Centre

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

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

Damian Green

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

Keith McNeil

Until February 2023

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

Previously, Prof McNeil has worked in 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.

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.

Tanya Kelly

From February 2023

Dr Tanya Kelly is the Acting Chief Clinical Information Officer and Acting Executive Director, Digital Health Branch, eHealth Queensland. She has an active role in clinical leadership and clinical strategic direction for digital health across the state-wide eHealth program.

Dr Kelly is also Chair of the Queensland Clinical Senate, a body that provides strategic advice to the Queensland public health system. She is an experienced and active senior clinician (anaesthetist) who has held clinical leadership roles for the past 10 years, most recently as Director of Anaesthesia and Perioperative Medicine and Clinical Director for Digital Transformation within the Sunshine Coast Hospital and Health Service. Beyond her clinical practice, she has qualifications in clinical redesign, business and is a Certified Health Informatician (CHIA).

Dr Kelly is keen to ensure that digitally enabled healthcare in Queensland is safe, highly effective and maximises the opportunities associated with digital technology, to provide a responsive healthcare system that meets the needs of consumers.

Lynne Cobiac

From August 2022

Lynne Cobiac is currently the Director (Acting) of CSIRO Health and Biosecurity business unit, having been Deputy Director for 6 years and a member of CSIRO's Science Council. She has over 30 years' experience and leadership in research and management in the health sector within both research organisation and university environments. Lynne established CSIRO's Precision Health Future Science Platform in 2018 between CSIRO and research and delivery partners, which then developed CSIRO's Future of Health report. She also was the Principal Investigator in establishing the Australian Health Biobank on behalf of the Department of Health and Aged Care. Lynne is currently a Board Member for the Melbourne Genomics Health Alliance, the Australian e-Health Research Centre, and the International Life Sciences Institute (SEAR).

Richard Symons

Minutes Secretary

Robert Miotti

Finance Manager, CSIRO

AEHRC around Australia

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

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

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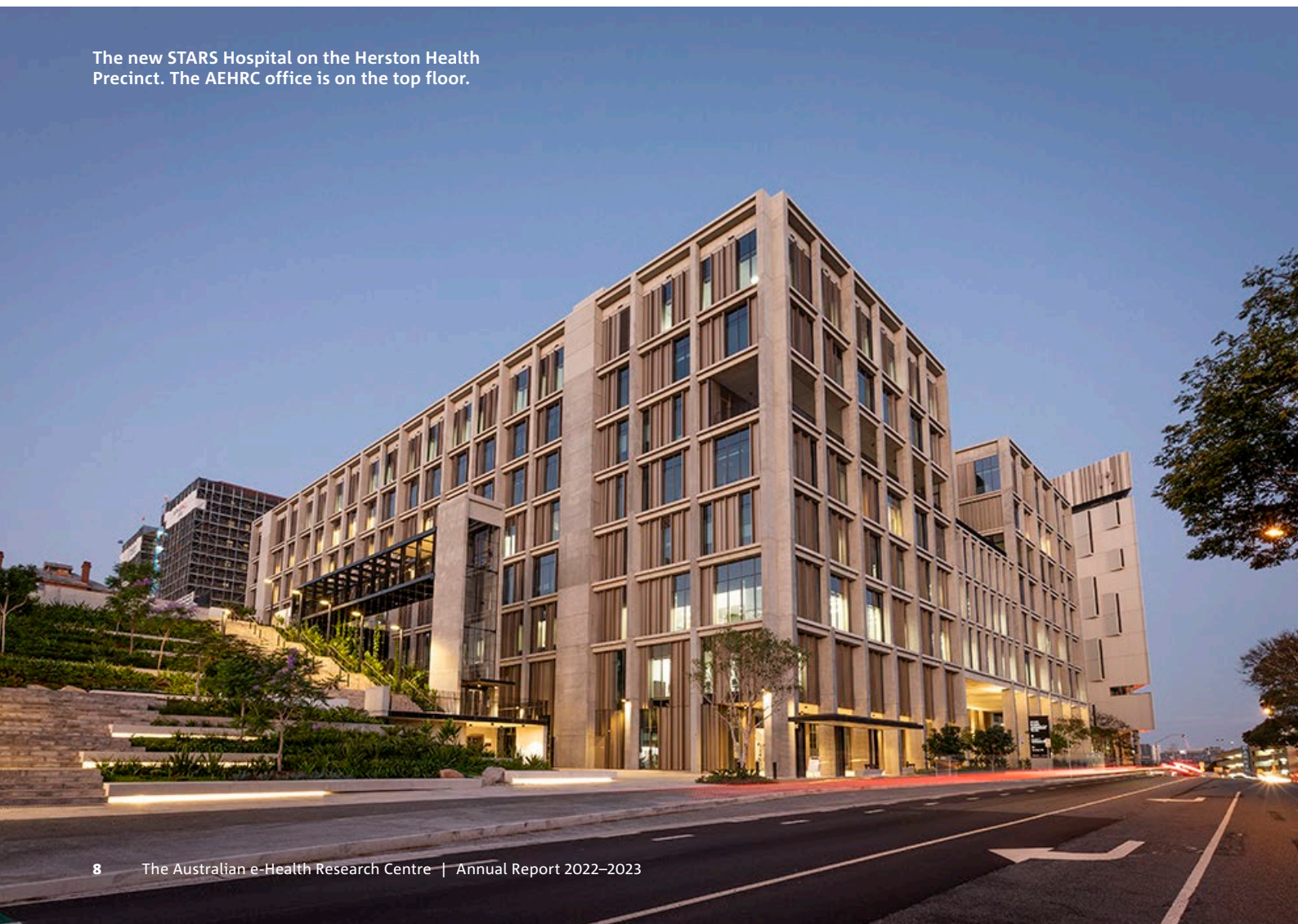
Queensland

Our AEHRC headquarters is in the new STARS Hospital on the Herston Health Precinct. We collaborate broadly across 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, James Cook University, Griffith University and Sunshine Coast University.

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

New South Wales

Our NSW based staff have recently moved into the Westmead Innovation Quarter as part of the new home for CSIRO Health and Biosecurity in Sydney. Sydney-based staff bring expertise across the whole program—including staff from our Transformational Bioinformatics, Health Services and Health Informatics groups.

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

Over the past 12 months we have increased our collaboration on the Westmead campus — with new collaborations with Westmead Hospital, NSW Pathology and eHealth NSW.

We have also had six new staff join us based in our Sydney office as part of our work delivering the National Clinical Terminology Service.

Our NSW engagement is led by our Team Leaders in Sydney—Lawrence Wilson, Sarah Kong and David Silvera.

Western Australia

Our Perth based staff are on the Kensington CSIRO campus.

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

The team's project reports are in our Digital Therapeutics and Care group section where we detail our collaborations with Fiona Stanley and Royal Perth Hospitals, as well as the University of Western Australia. The 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 where 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 moved into refurbished offices at the CSIRO Parkville site and are part of multiple different groups—including Health System Analytics, Biomedical Informatics and Health Data Semantics and Interoperability.

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).

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

AEHRC leadership

Dr David Hansen

CEO and Research Director, Australian e-Health Research Centre

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

David is a member of the Australian Digital Health Agency Clinical and Technical Advisory Committee, member of the National Steering Committee for the Australian Genomics Health Alliance and board member of the Australasian 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 Michael Lawley

Group Leader, Health Data Semantics and Interoperability

Dr Michael Lawley leads the Health Data Semantics and Interoperability group with teams in health informatics and modelling, clinical terminology and interoperability, natural language processing and information retrieval, and software engineering. The group's focus is on improving healthcare delivery and outcomes through improvements in the quality and use of digital health data during collection, exchange, and analytics.

Michael has extensive expertise in clinical terminology, specifically large-scale ontologies such as SNOMED CT and is a leading contributor to HL7's FHIR Terminology Services standard. 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 for precision health (prediction, staging, prevention and treatment), including when combined with various omics, neuropsychology, smart sensing, and clinical phenotypes.

Dr Denis Bauer

Group Leader, Transformational Bioinformatics

Dr Denis Bauer leads the Transformational Bioinformatics Group and is an internationally recognised expert in machine learning and cloud-based genomics. She is an Adjunct Associate Professor at Macquarie University and AWS Data Hero, determined to bridge the gap between academia and industry. Denis holds a Bachelor of Science from Germany, a PhD in Bioinformatics from the University of Queensland and a Certificate in Executive Management and Development from the University of New South Wales Business School.

Her research has led to the discovery of novel disease genes for Motor Neuron Disease and has informed the COVID-19 vaccine development. She keynotes international 10,000-attendee IT, LifeScience and Medical conferences and has attracted more than $41M in funding to further health research and digital health. She develops open-source bioinformatics software that has commercial impact through cloud-deployment. She was recognized as Brilliant Women in Digital Health 2021 and Women in AI 2022 and published a senior author paper in *Nature Biotechnology* in 2023.

Dr Marlien Varnfield

Group Leader, Digital Therapeutics and Care (DTaC) Group

Dr Marlien Varnfield is a Principal Research Scientist and leads the Digital Therapeutics and Care Group, overseeing innovative approaches to improve health outcomes for older people, people living with disability, and those with chronic health conditions. Marlien holds a Master of Science (focusing on periodontal diseases) and her PhD research at the Department of Epidemiology & Preventive Medicine, Monash University, focused on evaluating the potential for large scale implementation of health-care interventions utilising Information and Communication Technologies.

The impact of Marlien's research includes translation of health research into implementable, tangible outcomes. She was key driver behind the development of AEHRC's world leading mobile health research program including the world first validation of remote delivery of cardiac rehabilitation and development of the M♡THer platform for management of gestational diabetes, which has benefited >6000 women since June 2020.

Dr Rajiv Jayasena

Group Leader, Health System Analytics and Victorian Lead

Rajiv leads the AEHRC's Health Systems Analytics group, comprising research teams specialising on hospital patient flow, operational and clinical decision support tools, syndromic and disease surveillance and response systems, implementation evaluations of new and improved models of healthcare and two AEHRC wide programs of activity, health data engineering and quality management system (QMS) which facilitate standards, interoperable software engineering and regulatory compliance our solutions to be scalable-ready for future opportunities.

Dr Janet Fox

Business Development Manager

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

Annual e-Health Research Colloquium

Have you ever wondered what your healthcare will look like in the future?

And by 'future' we don't just mean in 30 or 40 years. We mean a future as early as a few years away.

This year's annual research colloquium featured digital health scientists and industry partners from around the country hit the podium to reveal some of the big-ticket items for digital health.

And while much of the research presented is still in its early stages, you can expect to see some of the work implemented into health systems earlier than you might think.

Some of the most life-changing research that came out of the colloquium involved a big word that doesn't sound particularly transformative: interoperability.

One of the biggest burdens faced by clinicians and patients in a digital health system is the exchange of information. Or put more simply, the fact that different online information cannot talk to each other.

Imagine a world where forms can pre-populate so there's no need to fill out your details (again). Or where your doctor can easily access your medical record so they know what medications you're on.

Interoperability is the key, and it's being made possible by the work of scientists at AEHRC.

Enter Sean Fong, ex-vacation student at CSIRO and now research scientist. Sean is working on SMART apps that use a standard called FHIR (or 'Fast Healthcare Interoperability Resources') to allow health information to be shared securely and seamlessly. This sharing of data means more time for consultations and less work for patients and their healthcare professionals.
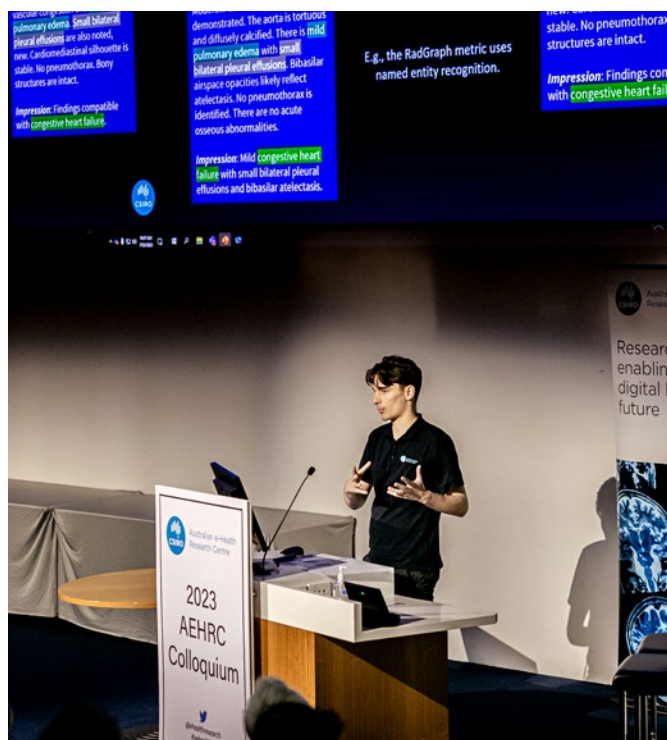
Another big topic on everyone's lips at the moment is anti-microbial resistance (or AMR).

And so it should be.

Antimicrobial resistance is one of the greatest threats facing humanity. Bacteria and other microbes are acquiring and developing increased resistance to the drugs designed to kill them. This growing resistance is largely due to our overuse and misuse of antimicrobials, such as antibiotics, in human and animal medicine.

Dr Teresa Wozniak and her team are making headway into combatting antimicrobial resistance through their platform HotSpots, another tool that facilitates the sharing of medical information.

HotSpots is a digital surveillance program that helps doctors choose the 'right drugs for the right bugs'. The platform allows doctors, nurses, and Aboriginal health practitioners across regional Australia to access up-to-date information about antibiotic resistant clusters. Teresa told the colloquium audience that to date, the impact of Hotspots has been the integration of data into other data surveillance systems, the development of treatment guidelines, as well as training on antimicrobial resistance for an Indigenous workforce.

On another front, artificial intelligence (AI) and machine learning could one day help clinicians diagnose and treat patients. Dr Denis Bauer's team took us on a tour of the wonders of precision medicine. Dr Letitia Sng revealed ground-breaking research into using genomics and machine learning to identify people at risk of coronary artery disease, and Denis showed off technology to help identify disease mutations.

Dr Aaron Nicolson told us about his research teaching machines how to support radiologists by diagnosing X-rays.

More from the AI and imaging front came from Dr Filip Rusak. He presented his research, which is already being used by clinicians, using AI to develop a world-first benchmark for measuring brain atrophy – or thinning – in neurodegenerative diseases, including Alzheimer's disease.

So, from interoperability to genetics to AI, the colloquium set the agenda for healthcare that's accessible, timely and effective. Not one of the 400 attendees left without at least some hope for a healthier future.

Awards

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

- Natalie Twine received a Brilliant Women in Digital Health award 2022 from Telstra Health, the award ceremony was in October.

- Jessica Rahman received the best EMCR poster award at Westmead Research and Innovation Conference 2022.

- Aida Brankovic was one of the three finalists for the Global Australian Award 2022 in the Global Talent category.

- James Doecke, Marcela Cespedes and Timothy Cox won second prize using the Alzheimer's Disease Data Initiative NeuroToolKit (NTK) application in the ADDI-Roche Hackathon.

- Jim Steel received a 10-year Most Influential Paper award for a paper in the Journal of Software Systems and Modelling about model interoperability in building information modelling.

- Aaron Nicolson was a winner at the global ImageCLEF competition.

- Alana Delaforce won best overall paper from the University of Newcastle for 2022 within the school of Nursing and Midwifery.

- Aida Brankovic won the Best Paper Award at Medinfo23 for her co-authored paper, 'Elucidating Discrepancy in Explanations of Predictive Models Developed Using EMR'. Other authors were Wenjie Huang, David Cook, Sankalp Khanna, and Konstanty Bialkowski.

CSIRO recognition

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

- David Silvera was awarded a CSIRO Julius Career Award.

AEHRC Supporting Melbourne Genomics

The Melbourne Genomics Health Alliance was formed in 2013 with the collaborative vision to bring genomics into healthcare. With members from across Victorian hospitals, research and academic institutions, Melbourne Genomics has led the way in introducing genomics into clinical care. Over the past 10 years CSIRO has played a key role in supporting the Melbourne Genomics program.

Leading CSIRO's involvement, the Australian e-Health Research Centre has contributed key staff and technology to the Melbourne Genomics approach to genomic and clinical capture and data sharing. AEHRC teams have also undertaken collaborative projects in cloud computing, benefits realisation, chatbots for genomic counselling, and many others over the years.

Melbourne Genomics has achieved some amazing outcomes over the past 10 years. This includes over 3000 Victorians receiving genomic testing through the program. Some of the results for patients have been life changing – identifying rare genetic causes for diseases and sparing patients from invasive testing. For example, patients who received a genomic test were nineteen times more likely to get an informative result than those tested with usual care.

The work of Melbourne Genomics has contributed to evidence for Medicare funded genomic tests including childhood syndromes, kidney disease, cardiomyopathies, and hearing loss.

A key part of AEHRC's contribution has been the design and development of the Genomical software.

The Genomical platform orchestrates a genomic test from beginning to end, including sharing data with other laboratory systems and even electronic medical records. Key to Genomical is its use of cloud computing at every step. AEHRC is proud that our terminology server, Ontoserver, is part of the Genomical platform and that our bioinformatics cloud software, sBeacon, enables the exchange of variant information with international Beacons to identify patients with similar rare diseases. Genomical is now used in six leading medical laboratories in Melbourne and beyond.

With the Alliance's program is coming to an end in 2025, its focus will transition to equipping Victorian health services with the knowledge, tools, and evidence to progressing genomics and enabling its ongoing use in clinical care. Special acknowledgement to our staff who have been seconded to Melbourne Genomics over the past 10 years—including James, Kate, Ian, Matt, Tim and Nisha—great work team. And a big thank you to Clara, Natalie and the rest of the Melbourne Genomics team for a wonderful collaboration.

The Health Data Semantics and Interoperability group

Group Leader:
Dr Michael Lawley

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

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

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

Health Data Semantics and Interoperability science and impact highlights for 2022/23

- **Research grants:** We successfully secured multi-year funding from several grant applications including the MRFF DIFFERENCE project to improve Indigenous maternal healthcare.

- **NCTS:** Following awarding of a contract by the ADHA to operate the National Clinical Terminology Service (NCTS), we completed the transition activities and commenced a program to integrate the Australian Medicines Terminology (AMT) with SNOMED CT's new drug model and deliver AMT v4.

- **FHIR Accelerator:** Recognising our expertise in FHIR and capability and track record in building community and consensus through work such as the Primary Care Data Quality project, we were awarded more than $9M over two years in the Federal Budget to establish a community-led specification development process that engages all stakeholders, leveraging CSIRO's expertise in community building and FHIR tooling to act as the community coordinator and deliver supporting infrastructure.

- **Publication highlight:** In collaboration with the Transformational Bioinformatics group, we co-authored a Nature Biotechnology paper about the world's first query engine for genomic and medical data, which scales to millions of patient samples.

- **Licensing:** Ontoserver is now the national terminology server for eight countries: NHS England, NHS Wales, NHS Scotland, New Zealand, Estonia, Sweden, Netherlands, and Australia, with additional licence holders in the United States, Canada, Germany, Switzerland, the ASEAN region and South America. We also have reseller and embedded licenses with Dedalus and Oracle Health (Cerner).

- **OSCAR:** The Oncology Search Clinician Assistant Registry was developed for the Queensland Children's Hospital and Queensland Children's Hospital Foundation to reduce the effort of searching for targeted treatments.

- **AMR:** Development of standards-based antimicrobial stewardship (AMS) decision support tools to support the tracking, tracing, and tackling of antimicrobial resistances in the emergency department.

Terminology Projects team

Team Leader: Kylynn Loi

The Terminology Projects 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.

FHIR Terminology and Tooling team

Dion McMutrie
From January 2022

The Health Data and FHIR team is comprised of engineers with expertise in the use of FHIR and clinical terminology to build and integrate digital health systems. We develop a range of tools to accelerate and promote the use of FHIR and related standards to build and integrate digital solutions in the health sector.

Data Semantics and Machine Learning team

Dr Bevan Koopman
From January 2022

Our research is about helping people find relevant and reliable health information to make health related decisions. We do this with a focus on natural language processing, search, and machine learning approaches.

We tackle problems where people need to find answers and make clinical decisions in the face of overwhelming amounts of typically unstructured data. This may occur in evidence-based medicine, where for instance clinicians need to search through vast amounts of literature and clinical trials to find a targeted treatment for a specific cancer. A solution might involve automating the processing of matching and recruiting a patient to clinical trials.

Our research is about:

1. how to build models search through unstructured natural language
2. understanding the semantics of someone's query rather than just matching keywords
3. how to inject medical domain knowledge into an AI model
4. putting the human searcher in the loop so they can bring their domain knowledge to guide the model to relevant information.

Health Data and Text Analytics team

Team Leader: Dr Anthony Nguyen

The Health Data and Text Analytics team develops and applies advanced AI techniques to enable complex, automated analyses of electronic health record data to support clinical decision-making and public health surveillance. In partnership with healthcare providers, the team creates value from structured and unstructured narrative health data to deliver innovative AI 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

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

CSIRO in Melbourne Genomics Health Alliance

Matt Nielsen

Our team embedded in Melbourne Genomics is crucial in helping uplift the technical infrastructure needed to support timely and efficient analysis of the large and complex data used in clinical genomic variant interpretation. The software solution, Genomical, has supported the analysis of over 15,000 patients in Australia to date and is positioned to support the burgeoning growth in the industry.

NCTS Office

Yi-Han Toh

The NCTS Office team is a dedicated central team who excels in coordinating and optimising a spectrum of functions, ensuring the smooth delivery of the NCTS services. Some of the key services the office team provides are:

Project management office to manage enhancements and maintenance projects for products and services:

- Release coordination for both terminology and tooling.
- Overall products and services management.
- Outreach and education initiatives that empower the community through engagements and knowledge sharing.
- Reporting against SLAs to the NCTS governance committees ensuring transparency and accountability.

Our team comprises seasoned industry professionals ranging from project managers, change and engagement managers and business analysts, each bringing a unique blend of skills and extensive knowledge. Together, we operationalise and execute the NCTS service delivery programme with the NCTS Content team and NCTS Terminology Tooling team.

NCTS Content

Sarah Kong

The NCTS Content team is a dedicated group of health professionals with diverse and extensive experience leveraged to deliver meaningful and useful terminology content for the National Clinical Terminology Service (NCTS) products: the Australian Medicines Terminology (AMT), SNOMED CT-AU (the Australian extension of SNOMED-CT), and FHIR Terminology Resources. We provide our stakeholders with their terminology needs as they work towards interoperability and providing connected care for the Australian community.

NCTS Terminology Tools

Luke Swindale

The NCTS Terminology Tools team develops and maintains the software tools used to author, review, release, and integrate clinical terminologies into the National Clinical Terminology Service (NCTS). These tools also enable clinicians and external consumers to work with terminologies, such as SCT-AU, AMT, FHIR terminology resources, and third-party content. The overall goal of the NCTS Terminology Tools team is to make it easier for end users to adopt clinical terminologies and to improve interoperability between systems. This is important because terminologies are essential for the effective communication and exchange of clinical information.

Health Data Semantics and Interoperability: platform technologies

Poor data quality and consistency resulting in a lack of – or poor – insights can compromise the quality and efficiency of care.

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

These include:

- FHIR-native terminology and classification tools: Ontoserver, Snapper, Snap2Snomed/Snapagogo, Snorocket, Shrimp, Atomio, Ontocloak, and SnoMAP
- OpenSource FHIR tools: RedMatch; Pathling
- Natural language processing tools: Medtex
- Search engines for medical reports and literature
- Chatbots to tackle a range health-focussed topics

Suite of FHIR native terminology tools

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

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

Ontoserver

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

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

- FHIR package support
- Significantly improved validation of SNOMED post-coordinated expressions
- Further pre-adoption of FHIR R5 features where no backward compatibility issues exist
- Extended support for new SNOMED CT expression constraint language features
- Support for $diff and PATCH operations
- Significant speed improvements to $validate
- Upgrades to support the additional requirements of the FHIR Implementation Guide tooling
- First beta-testing of FHIR R5 support

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 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.

Snap2Snomed/Snapagogo

Snap2Snomed is an open-source tool built and operated for SNOMED International to support collaborative mapping of term lists and local vocabularies to SNOMED CT. It builds on expertise developed with Snapper and leverages the automapping capabilities of Ontoserver to provide collaborative mapping to an international audience including SNOMED member countries and vendors such as Babylon Health.

Snapagogo extends the capabilities of Snap2Snomed by supporting additional target code systems hosted by Ontoserver such as LOINC, RxNorm, and ICD 10. A collaboration with the Australian Research Data Commons (ARDC) has commenced to make Snapagogo available to the Australian research community.

SnoMAP

SnoMAP is a suite of SNOMED CT to ICD10-AM mapping products that enables diagnoses to be recorded using SNOMED CT-AU and mapped to ICD10-AM codes. We have developed two products:

- **SnoMAP Starter**: a simple SNOMED CT-AU diagnosis to ICD-10AM Codes FHIR ConceptMap, to support the use and reuse of SNOMED CT for analytics and research activities.
- **SnoMAP ED:** a mapping service for emergency department non-admitted patient reporting purposes, thus supporting the use and re-use of the standard clinical terminology for ED funding activities. This has been revamped to support mapping directly to the IHACPA ICD10-AM shortlist. Read more in Health Data Semantics and Interoperability: Project Updates.

Snorocket

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

Shrimp

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

Supporting users around the world

Our clinical terminology and FHIR® enabled products are used globally to support the advanced use of SNOMED CT, management of ValueSets and ConceptMaps and syndication of clinical terminologies. Shrimp and our public testbed are used worldwide. Ontoserver is also licensed commercially by users in Australia, New Zealand, Switzerland, Germany, England, Wales, Scotland, Estonia, Sweden, France, and the United States, with evaluation licences in use across the United States, ASEAN region and South America. In the last 12 months NHS Scotland, Estonia, and New Zealand all went live with Ontoserver as their national terminology server, along with vendors in NZ, US, and UK.

Redmatch

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

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

Redmatch: Web editor

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

Leveraging the HAPI FHIR Server

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

Pathling

Pathling simplifies the use of HL7® FHIR® and clinical terminology within data analytics. It is built on Apache Spark and includes language libraries and a server implementation.

Pathling was designed to assist with these primary use cases:

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

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

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

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

Learn more about Pathling at https://pathling.csiro.au/.
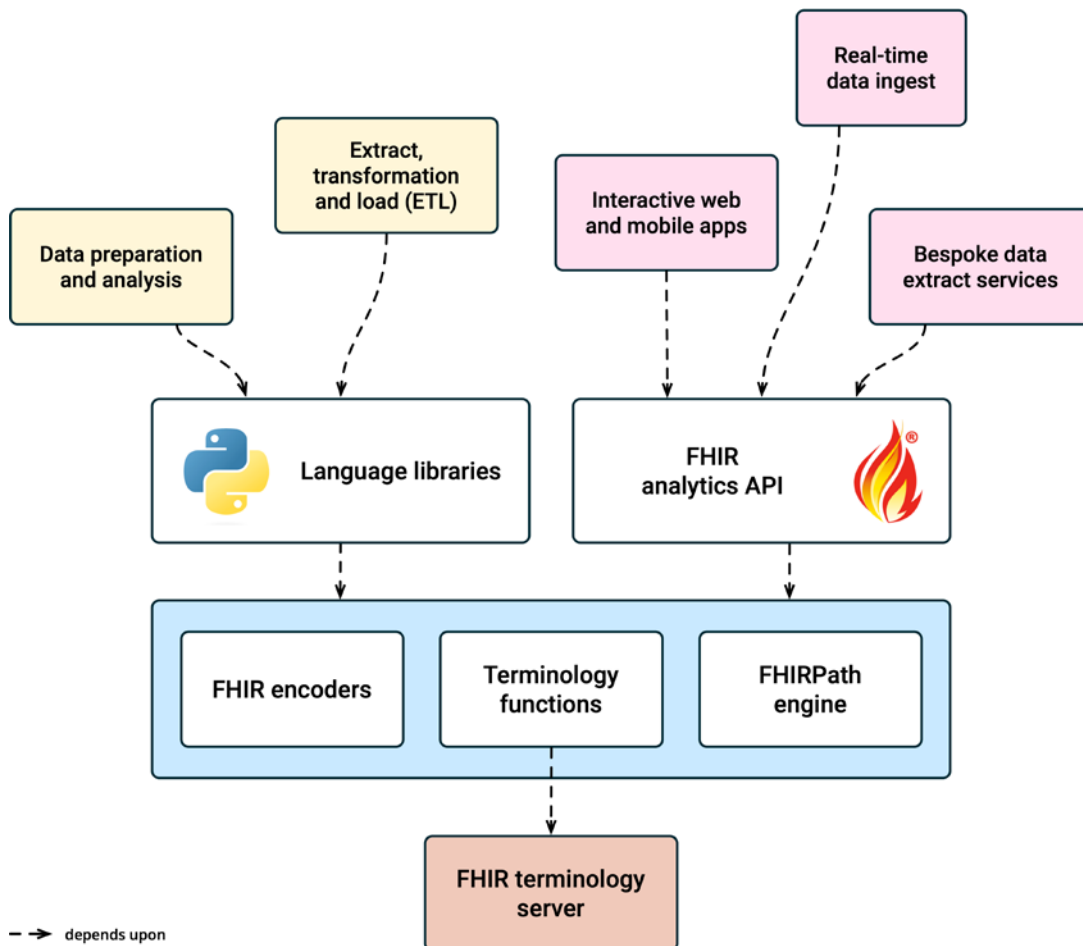
Pathling: components and their corresponding use cases

Natural language processing

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

Medtex

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

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

Analysis engines using 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.
- 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 utilised to deliver solutions to healthcare practitioners, including cancer registries, and hospital radiology and emergency medicine departments. These solutions encompass:

- Analysing pathology and radiology reports, and death certificates, to extract cancer characteristics important for assessing cancer incidence and associated mortality rates.
- Analysing pathology test results and discharge summaries to streamline test result reviews to identify patients undergoing inappropriate antibiotic treatments due to drug-resistant infections.
- Analysing medical reports to provide the capability for medical record searching and advanced analytics.

Read more in Health Data Semantics and Interoperability: Project Reports.
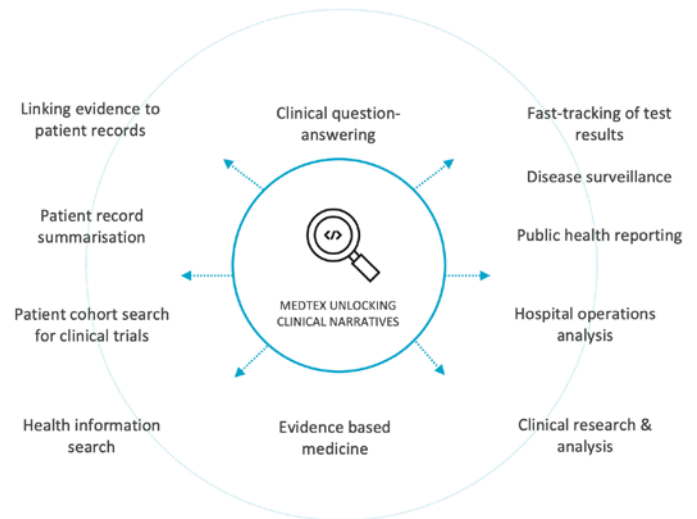
Medtex: Unlocking clinical narratives

Search engines for health data

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

We developed a suite of solutions for searching health data. Nowadays most of our work involves the training of AI models, specifically neural network models for ranking and natural language processing. These models are adept at understanding the meaning behind a user's query and the relevant information they are looking for, making them proficient at finding relevant information.

The development of our search technology is driven by the idea that people look for information to make important health decisions. As such, we develop solutions that support decision making, empowering users with the information they need rather than ceding control to a black box system.

Key technologies we have developed include:

- Evidence-based search systems capable of ingesting all of PubMed and all current clinical trials and suggesting relevant evidence to support clinical decision making.
- Automated the matching of patients to clinical trials (or visa versa).
- Targeted cancer treatment recommendation for children with specific genetic findings.
- Systematic analysis of human search behaviour in the health space to inform the development of better search engines.

Chatbots for health

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

- 'Dolores' a chatbot to discuss all things related to chronic pain with language suitable for the age of the user. Dolores has been piloted at pain clinics at the Royal Brisbane & Women's Hospital and Melbourne Children's Hospital.
- 'Quin' a smoking cessation chatbot built from thematic analyses of Quitline counselling sessions. Quin is being designed for long-term use and support for a user wishing to cease smoking.
- 'Aurora' a chatbot that administers a sleep-dependent memory test (developed at the University of Sydney) for people living with mild cognitive impairment. Auroroa handles the testing within a critical time window and reschedules if the user misses the test.

AEHRC chatbots can function on mobile devices without requiring internet access and have support for:

- Smart on FHIR
- Custom user interface widgets
- Voice logging and processing
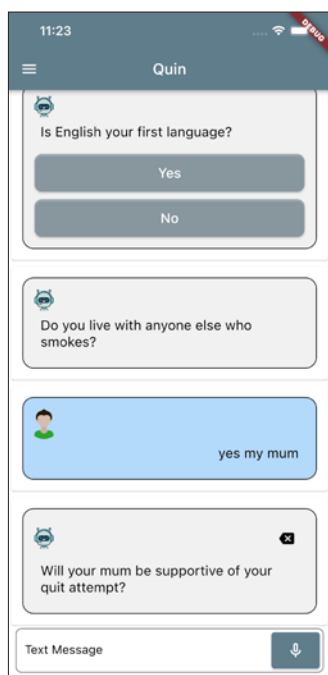
Example dialogues of Quin the smoking cessation chatbot. Here Quin is asking if anyone else lives with the user who smokes to anticipate triggers the user might be exposed to. The user may respond verbally, text or by drawing.

Health Data Semantics and Interoperability: project reports

The National Clinical Terminology Service

Collaborator: The Australian Digital Health Agency

The National Clinical Terminology Service (NCTS) is governed by the Australian Digital Health Agency (ADHA) and operated by AEHRC. Under a two-year service agreement, the NCTS will drive the healthcare community's digital health needs through:

- Managing, developing, and distributing national clinical terminologies and related tools, including SNOMED CT-AU and the Australian Medicines Terminology (AMT). This responsibility includes being the Australian National Release Centre for SNOMED CT on behalf of SNOMED International.
- Delivering two concurrent projects within 36 months: An AMT model redesign to align with the new SNOMED International medicines model, and a corresponding infrastructure and tooling uplift.

The initial key task focussed on a seamless transition of the NCTS operations and establishing essential organisational structures within CSIRO. A skilled team was transitioned from the ADHA to CSIRO without an interruption to the monthly clinical terminology publishing schedule. Collaborations between CSIRO and ADHA teams has refined operational processes and created a shared target operating model.

After the transition phase, project teams were formed for the AMT model redesign and infrastructure and tooling uplift. From Jan'23 to Jul'23, requirements were gathered through industry engagement, co-designing the new AMT model. A full prototype was tested with a working group, generating feedback for ADHA's assessment. Concurrently, the Infrastructure and Tooling Uplift project was initiated. Between Mar'23 to Jun'23, a gap analysis was conducted to evaluate the new tool capabilities will meet the content author's needs. Detailed release and content authoring processes were later defined to guide future tool application.

In the upcoming financial year, additional work is scheduled to expand the new AMT model's testing beyond the working group. The Infrastructure and Tooling Uplift project entails user acceptance testing and developing a new module to enhance existing functionalities.

Smart Health Checks

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

The Smart Health Checks project continues a journey to demonstrate how the adoption of foundational data standards in primary care can support better clinical outcomes, enhance the usefulness of information, and improve interoperability. Funded by the Australian Government Department of Health, through the First Nations Health Division, the Aboriginal and Torres Strait Islander Health Check assessment has been chosen as a case study to further understand Smart Forms technology and the standards underpinning it.

Smart Forms is a data capture solution for health assessments that conforms to the HL7 FHIR Structured Data Capture and SMART App Launch Implementation Guides. Community engagement and the co-design of a national data interoperability roadmap for primary care, identified SMART and FHIR as key foundational capabilities clinical software could implement to support several use cases.

The solution developed for this project includes an open-source reference implementation of an application (Smart Forms Application) that can be integrated into existing clinical systems and workflow. The SMART App Launch specification allows client applications to authorise, authenticate, and integrate with FHIR-based data systems. The Smart Forms Application can be launched from a clinical system in the context of a patient consultation to display a health assessment form to the user. Contextual information such as the patient and the practitioner, along with additional clinical information relevant to the patient can be retrieved from the clinical record to prepopulate the form, thereby reducing the burden of data re-entry. The application will display the form according to its underlying FHIR questionnaire definition and manage the workflow of completing it. It supports advanced rendering features like conditional display of items, in-built calculations that can be used to calculate things such as BMI and CVD risk and fully supports terminology encoded data fields and the use of a FHIR terminology server such as Ontoserver. All data exchange is performed through standard FHIR APIs and completed forms are stored in the clinical system that launches the application.

A Smart Forms FHIR Implementation Guide has been developed and includes a FHIR questionnaire that defines the Smart Form for the Aboriginal and Torres Strait Islander Health Check assessment. It also specifies the expectations and capabilities of clients and servers participating in this ecosystem.

Smart Forms format

Automating cancer data registries to enhance data quality

Collaborators: Cancer Alliance Queensland (CAQ), Queensland Health

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

Medtex is unique in that it targets the full range of cancers as opposed to tumour specific extractions used in other systems and studies. It aims to improve the current cancer notification workflow and abstraction processes for the Queensland Cancer Register.

In collaboration with CAQ, continual improvements and extensions to Medtex include the extraction of a broad range of cancer information such as cancer stage and cancer recurrences across a multitude of cancers. These are important determinants of cancer survival. As the effective cancer stage is dependent on full access to both public and private pathology and radiology reports from across the State, CAQ and CSIRO are ensuring that Medtex solutions are generalisable, scalable, and performant across different providers and report types.

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

Medtex for the notification of electronic cancer pathology reports and the coding of notifications data including synoptic and staging information. Medtex processes narrative pathology reports and generates structured data with attentional mechanisms for explainability to aid clinical coders in cancer abstraction tasks.

Digital health standards-based antimicrobial stewardship (AMS) decision support

Collaborators: The Prince Charles Hospital ED, Pathology Queensland

Digital health standards-based tools, based on the FHIR healthcare interoperability standard, were developed to support the tracking, tracing, and tackling of antimicrobial resistances (AMR) in the emergency department.

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

The first application is launched from an EHR to provide a convenient and clear visualisation of a patient's microbiological culture sensitivity history. The second provides hospital-level susceptibility data in the form of

a dynamic antibiogram, which allows users to visualise susceptibility rates (generated using Pathling, an analytics FHIR server) and apply filters to personalise data to certain demographics and infection types. The third is a test result review app reconciling information from microbiology test results and patient discharge summaries to alert emergency physicians of drug-bug mismatches and hence when a change of antibiotic treatment might be needed. We'd be also able to use the data to provide hospital level summaries of prescriptions and test results to monitor the appropriate use of antimicrobials.
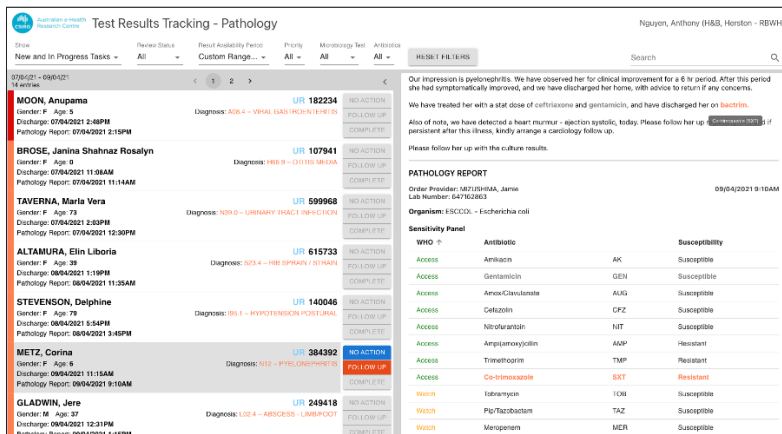
Optimising the use of current antibiotics will enhance the quality of antibiotic prescribing decisions for patient benefit and to minimise AMR. Digital AMS solutions that further consider the impact of the patient's specific characteristics including their AMR and infection history can lead to the development of individualised antibiotic prescribing recommendations. Ongoing research into personalised, data-driven, evidence-based decision support AMS tools that are safe and effective may have the utility to further improve antibiotic prescribing.

Patient-level microbiology results app summarising a patient's history of AMR and infections.

Dynamic antibiogram app enabling AMR profiles on certain patient cohorts to be analysed and visualised.

Microbiology test result review app (with obscured patient information) identifying and prioritising patients with inappropriate antibiotic treatments due to drug-resistant infections for patient follow-up, streamlining the clinical review process in Emergency Departments.

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

Automatic identification of patients presenting with pain to the emergency department

Collaborators: 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. Deep learning, a subset of artificial intelligence, has played a crucial role in addressing the challenges associated with identifying and documenting pain accurately during triage.

A generalised incremental multiphase framework was proposed for developing robust and performant clinical text deep learning classifiers. It incorporated incremental multiphases for training data size assessments, a cross validation setup to avoid test data bias and inter/intra-model significance testing for robustness assessments. The task of identifying patients presenting in 'pain' to the emergency department demonstrated the efficacy of the approach – verifying the effectiveness and generalisation of the framework on a dataset of 10k records.

The resulting clinical text deep learning model was deployed on three years of data consisting of over 250k presentations from the same large inner-city adult ED. The use of the clinical text deep learning model has been effective at identifying the prevalence of pain on arrival to the ED from the narrative assessment completed on arrival to the ED. The ability to identify pain at a population level has allowed a robust description of the population, its treatment, and the impact of a pandemic on these outcomes. Changes in care associated with the pandemic were closely tied to changes in society and the response of the healthcare system to this major event.

Generalised incremental multiphase framework

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

Collaborator: Logan Hospital Emergency Department, Queensland Health

Chest pain is a disease entity requiring a process of investigations and appropriate interventions. It has never been fully incorporated in a clinical registry setting in Australia, despite consistently being in the top ten presenting complaints to EDs and costing the Australian economy $6.8 billion in loss of income and health expenditures in the 2017-2018 financial year alone. Improving the delivery of health outcomes is dependent on an up-to-date clinical data registry.

An ED chest pain clinical data registry was built from automatically extracted clinical information from both unstructured clinical notes and structured data sources of patients presenting to the ED with possible cardiac chest pain.

Deep learning models that leverage task-specific unlabelled data were developed to boost the performance of classification models for the risk stratification of suspected acute coronary syndrome. By leveraging large numbers of unlabelled clinical notes in task-adaptive language model pretraining, valuable prior task-specific knowledge was attained. Based on such pretrained models, task-specific fine-tuning with limited labelled data produced superior performances. Extensive experiments demonstrated that the pretrained task-specific language models using task-specific unlabelled data significantly improved the performance of the downstream models for the risk stratification classification task.

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 can 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 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

Domain and task-adaptive approaches to clinical text classification, (a) Typical transformer-based language model (LM) approach with two consecutive pretraining phases on general unlabelled text and domain-specific unlabelled text (DAPT) from the task domain and a fine-tuning step on task labelled data (TAFT), and (b) Task-adaptive transformer-based LM approach with additional task-adaptive pretraining step (highlighted in red box) on task-specific unlabelled data (TAPT) followed by a task-adaptive fine-tuning on task's labelled data (TAFT).

Precision medicine search engine for paediatric oncology

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

Cancer is a leading cause of death for Australian children. To improve patient outcomes, clinicians are seeking treatments personalised to a patient's genetics.

Finding treatments that match an individual's genetics amongst the vast body of medical literature and clinical trials is challenging. A search system tailored for clinicians to address this problem.

The search engine retrieves PubMed articles and clinical trials. It incorporates features such as query suggestion, which helps clinicians formulate otherwise difficult queries. An AI-driven matching algorithm deciphers the user's query and retrieves relevant treatments. The results are presented as a knowledge graph to improve interpretability.

The system will significantly reduce the difficulty of searching for potentially life-saving treatments that may otherwise have been missed.
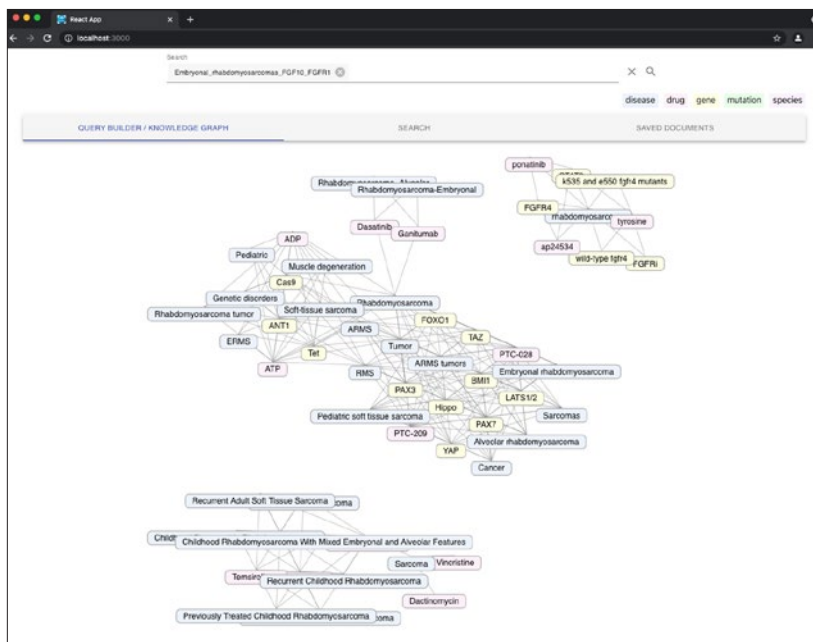
Screen shot of precision medicine search engine. Traditional search results can be viewed as a 'knowledge graph' indicating the relation between genes, drugs and cancers. This allows clinicians a quick overview of the treatment landscape and the ability to home in on targeted treatments.

Health Data Semantics and Interoperability: project updates

Queensland Clinical Terminology Service

Collaborator: eHealth Queensland

Implementation support is being provided to Queensland Health, who have new launched the Queensland Clinical Terminology Service (QCTS) at https://www.terminology. health.qld.gov.au. The QCTS adopts our Atomio and Ontoserver applications to support terminology content. Several systems across Queensland Health have been identified as first users of the service.

Health Studies Australian National Data Asset community connect project

A community connect project has recently been initiated to inform and educate the clinical trial community in Queensland about the Health Studies Australian National Data Asset (HeSANDA). The project culminates in a series of virtual and in-person workshops and the design of a series of videos.

The next phase of the project will expand the HeSANDA catalogue to include cohort studies and registries.

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). The NTCTS 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. Implementation support will continue to be provided.

Indonesia Clinical Terminology Service

Collaborators: Australian Government Department of Foreign Affairs and Trade and Indonesia Digital Transformation office

CSIRO is working with DFAT to assist Indonesia's Digital Transformation Office (DTO) in deploying and integrating an Indonesian Clinical Terminology Service. We hosted a delegation from DTO in February which included presentations on work from across the program, visits to local health facilities, and discussions about opportunities and strategies for accelerating uptake of clinical terminology in the Indonesian health system. DTO have since signed an Ontoserver license and commenced a proof-of-concept implementation. CSIRO and DTO are co-organising a Connectathon event to be held in Jakarta in late 2023.

SNOMED CT in QLD digital hospital projects

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

Continued collaboration with Queensland Health's Office of the Clinical Information Officer (OCCIO) is supporting the use of SNOMED CT in the Cerner ieMR product deployed in Queensland hospitals. This includes providing education and support around the use of SNOMED CT in surgery, emergency departments and trauma, particularly during terminology updates.

Support and maintenance of SNOMAP-ED is also being provided. SNOMAP-ED takes original SNOMED CT-encoded patient data recorded by emergency department clinicians and transforms it to qualify for activity-based funding. The tool is being used in Queensland digital hospitals to allow 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. As a result, Queensland digital hospitals can submit data for activity-based funding in near real time.

RANZCR project

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

A standards-based set of codes was developed to support the electronic requesting of radiology investigations. The pilot Radiology Referral Set (RRS) consists of 20 radiology services coded using SNOMED-CT and machine-readable artefacts to support the adoption of the terminology by software vendors. Guidance for the use of these artefacts includes starter implementation guidance for requesting and receiving systems (RRS) and guiding principles for the ongoing development of the RRS after this project.

Aged Care Data Compare Plus project

Collaborator: Digital Health CRC, University of Queensland, Regis Aged Care, AutumnCare

The Aged Care Data Compare Plus project implements and evaluates the use of data standards and technologies to support quality of care benchmarking and quality indicator reporting. An Aged Care Quality Indicator App that leverages Smart Forms technology and FHIR data exchange standards is being developed. The technology will be trialled as a solution to ease the burden of quality indicator reporting requirements, while providing a standard data representation that can be used for further analytics and risk adjustment.

GP National Antimicrobial Prescribing Survey project

Collaborator: National Centre for Antimicrobial Stewardship (NCAS)

The General Practitioner (GP) National Antimicrobial Prescribing Survey (NAPS) project saw the development of a FHIR Implementation Guide to specify data requirements for GP systems to adhere to when exchanging information. The goal was to facilitate standardised exchange of antimicrobial prescribing practice data.

The project included a comparison of the GP NAPS data requirements with other prescribing specifications in Australia: Real Time Prescription Monitoring (RTPM) and Electronic Prescribing (ETP).

The GP NAPS data requirements were also compared with GP desktop software user interfaces to evaluate the extent to which the software could align with the requirements.

Injury terminology classification

Collaborator: Jamieson Trauma Institute (JTI)

An injury classification system was developed in collaboration with JTI. The system enables injury-related encounters to be identified and their SNOMED CT, ICD-10-AM and AIS codes to be categorised according to 'Nature of Injury', 'Body Region', and 'Body Structure'.

These mappings were published as FHIR resources, enabling researchers to apply them to their data using Pathling and Ontoserver. This allows this content to be distributed across Queensland Health using the Queensland Clinical Terminology Service (QCTS).

The quality and coverage of the system were validated using emergency department data sets from the Princess Alexandra Hospital, Queensland Children's Hospital, and Royal Brisbane and Women's Hospital.

Automation of Australian Medicines Terminology modelling

Collaborator: Australian Digital Health Agency

As the national standard terminology for describing medicines, the Australian Medicines Terminology (AMT) is a key enabler of medicines interoperability. AMT is authored manually by a team of pharmacists and released monthly by the Australian Digital Health Agency (ADHA). To create efficiencies in maintaining the AMT, algorithms are being developed to automatically produce AMT from drug registration information in the Australian Register of Therapeutic Goods (ARTG).

The proposed algorithms detect ingredients and their unit measures as well as strength values from the ARTG drug summary. Use of the algorithms resulted in improved accuracy compared to the baseline method. This demonstrates the viability of developing a complete system to extract all information necessary to accurately convert drug summary data into the AMT data model.
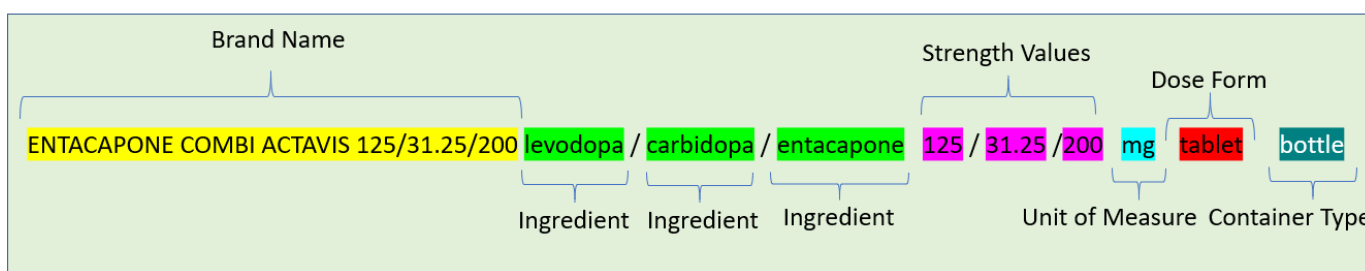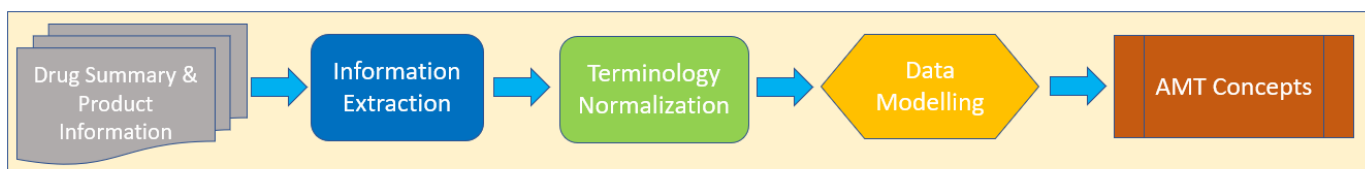
The proposed algorithms extract drug information, including ingredients, their unit measures, and strength values, from the ARTG drug summary. The data is converted into the AMT data model with a high degree of accuracy.

Melbourne Genomics Health Alliance

Collaborator: Melbourne Genomics Health Alliance (Melbourne Genomics)

The AEHRC continues to lead CSIRO's involvement in the Melbourne Genomics Health Alliance. This includes contributing to the development of Genomical, a software solution for laboratories that conduct clinical genomic testing. Genomical is used by 6 genomics labs across Victoria, including multiple major hospital laboratories in metropolitan Melbourne. The platform, which now services both germ line and somatic (oncology) workflows, is facilitating clinical grade exome, whole exome, and whole genome sequencing. Genomical is also enabling the efficient analysis and curation of sequence data and the return of interpreted clinical reports.

In addition, the AEHRC supports Melbourne Genomics with expertise in product architecture, patient-centric design, and FHIR interoperability. This facilitates closed loop e-Orders and e-Results integration with the Parkville Precinct Electronic Medical Record. The AEHRC also assists Melbourne Genomics in utilising OntoServer to access SNOMED CT, LOINC, and Human Phenotype Ontology (HPO) to support semantic interoperability of clinical genomics.

Digital health software project course 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 2022. 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. A small but enthusiastic cohort of students worked with a group of clinical stakeholders, with student groups building SMART-on-FHIR apps. Professor Braunstein's Health Informatics on FHIR online course was further expanded to include more 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.

The course will be offered again in semester 2, 2023. An increased focus on advertising, as well as a growing cohort of students, has seen enrolments in the course balloon to 73 students, with a corresponding growth in the external clients involved in offering projects.

Case based learning on FHIR

Collaborator: University of Queensland

The case-based learning tool that CSIRO produced for the UQ School of Medicine expanded its functionality again throughout 2022–23. The tool, which includes a case authoring tool, a case player, tutor dashboard, and a manager console, was integrated with CSIRO's open-source Pathling tool to allow course coordinators to perform learning analytics based on the FHIR data captured in the tool.

The tool was licensed and deployed by the University of Melbourne's School of Nursing for their curriculum, and the coordinators of those courses published a paper at MedInfo 2023 describing their use of the tool and its learning outcomes. University of Melbourne is planning to increase and broaden their use of the tool in 2024. Professor Mark Braunstein also presented a MedInfo paper describing the tool.

ARDC HeSANDA Project

Collaborators: ARDC, Health Translation Queensland, Queensland Cyber Infrastructure Foundation

The HeSANDA (Health Studies Australian National Data Asset) program is a strategic partnership with the Australian health research community to build a distributed national data asset from the outputs of health studies to support health data sharing and secondary use. HeSANDA will make health and medical research data easier to find, access, share and reuse, resulting in a reduction in research waste and improved researcher collaboration. It will increase Australia's return on health and medical research investment by reusing existing data to inform new research questions and initiate new research collaborations and lead to improved health outcomes for patients.

The AEHRC, along with its partners, was one of nine nodes who was successfully awarded $300k in funding to join this initiative in September 2021. The Queensland node implemented a Dataverse instance, as its operational platform, to facilitate the collection of the clinical trial metadata.

Once the information has been entered on the Dataverse platform, a DOI (digital object identifier) is minted for this dataset and is harvested to appear in the Health Data Australia catalogue.

A community connect project, culminating in a series of virtual and in-person workshops and the design of a series of videos, has recently been initiated to inform and educate the clinical trial community in Queensland about HeSANDA.

The 3,000 Genomes project: using machine learning and artificial intelligence for robust culture-independent susceptibility testing

Collaborators: Pathology Queensland, University of Queensland, AMR Mission

Antimicrobial resistance is a growing threat with newly emerging resistance genes rapidly spreading in our hospital system.

However, while species level identification from genomic data is relatively straightforward, detection of the presence of antibiotic resistance genes is not always reliably predictive of phenotypic susceptibility. For rapid genomics-based diagnostics to be fully realised in clinical practice, we need predictive algorithms to robustly guide safe and effective antibiotic therapy. The prediction of resistance in bacteria is challenging because of complex underlying mechanisms and high rates of acquisition of resistance determinants via horizontal gene transfer.

In collaboration with Pathology Queensland and the University of Queensland, this project develops bespoke reliable machine learning analysis workflow to optimise rapid resistance prediction of antibiotic susceptibility from whole genome data for common bacterial pathogens.

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

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

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

We have extended our collaboration with Pathology Queensland and the University of Queensland to also include Metro North Hospital and Health Services to implement a FHIR-based bioinformatics pipeline. This pipeline provides seamless integration of non-standardised data from the pathology laboratory and emergency department to a FHIR server, enabling a platform to build SMART-on-FHIR apps and a standardised API for accessing the data. This is enabling easier access to data for ward visualisation, dynamic analysis and reporting of outbreaks within a hospital setting.

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

How effective are large language models like ChatGPT at answering health related questions?

Collaborators: Queensland Digital Health Centre (QHDeC), University of Queensland

As people depend increasingly on generative large language models (LLMs) like ChatGPT, it is critical to understand model behaviour under different conditions, especially for domains, such as health, where incorrect answers can have serious consequences.

While AI tools like ChatGPT have exploded onto the scene of late, there is very little rigorous evaluation of both their effectiveness and how different conditions impact the answers they give.

We empirically evaluate ChatGPT to show, not just its effectiveness, but reveal that knowledge passed in the prompt can bias the model to the detriment of answer correctness.

In this preliminary study, we hope to shed some light on these important concerns about using such systems. In addition, this work can help develop more robust and transparent question-answering systems based on generative large language models. Indeed, based on our findings we are now developing new LLMs that provide answers backed by reliable evidence sources.

Improving antimicrobial dosing in critically ill patients

Collaborator: Metro North Hospital and Health Service (MNHHS; Royal Brisbane and Women's Hospital, The Prince Charles Hospital, Redcliffe Hospital), The University of Queensland

Difficult-to-treat infections include those that are caused by multi-drug resistant organisms, require prolonged antimicrobial therapy and cause patients to be acutely unwell and require life-saving interventions. Patients with these types of infections exist throughout the hospital system and are at high risk of poor outcomes, including death. A large proportion of the morbidity and mortality associated with these infections can be attributed to suboptimal antimicrobial therapy, including ineffective dosing that may also lead to the emergence of antimicrobial resistance.

A potential game-changer to address profound antimicrobial dosing challenges is the use of precision dosing, whereby dosing is personalised for the patient considering all available data including pathogen susceptibility and measured antimicrobial concentrations. The project aims to partner key groups and develop and validate via end-user (i.e., clinicians) assessments a proof-of-principle dosing software solution feasible for MNHHS, Queensland and beyond.

Twelve months of spatial tracking of tobacco and vape retail using the Google Maps API

Collaborator: Queensland Health, University of Queensland

Given the numerous health and safety concerns with the consumption of tobacco and vaping products, the density of retail outlets that provide these products, the social areas they operate in, and their proximity to other sensitive establishments, is of concern. The aim of this project was to investigate the usefulness of using Google Maps to identity, track and compute the density of tobacco and vaping retail throughout Queensland. With data obtained between July 2022 and June 2023, the key findings were the number of retail stores in Queensland that provide both vape and tobacco products increased by 42% and there are statistically significant associations between tobacco & vape retail density, socio-economic indices and the number of schools in a suburb when predicting the probability that a suburb has a tobacco shop.
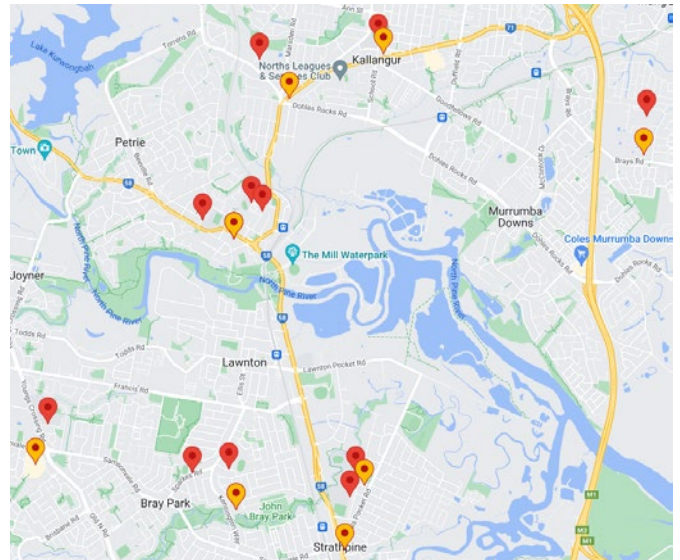

Example Google Map of tobacco/vape stores (yellow pins) and schools within close proximity (red pins).

Quin: Smoking cessation chatbot

Collaborator: Prince Charles Hospital, University of Queensland

Quin is a chatbot designed to act as a long-term, virtual companion throughout the smoking cessation journey. Quin provides education and advice on all aspects of smoking cessation and logs the progress of the user. A large component of Quin's chatbot brain is developed by a mixed-method analysis of Quitline transcripts.

This includes smoking history, answers to frequently asked questions and information of pharmacotherapy. Further responses and conversation flows were designed by multi-disciplinary team consisting of a thoracic medicine specialist and health behavioural psychologist, tobacco control expert and a public health PhD student. Quin has been demonstrated in focus groups for various stakeholders and is currently undergoing iterative development for future use in trials.
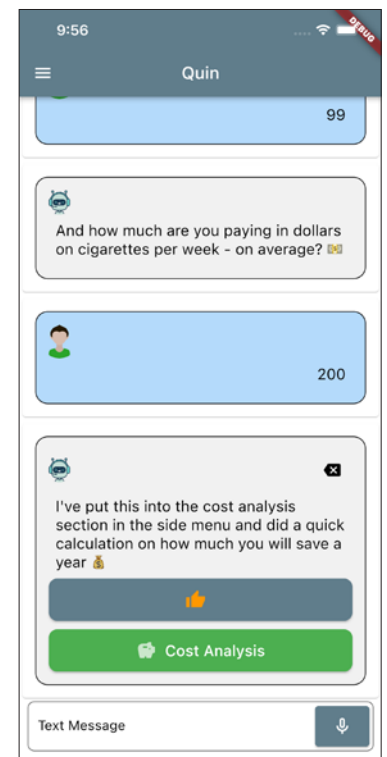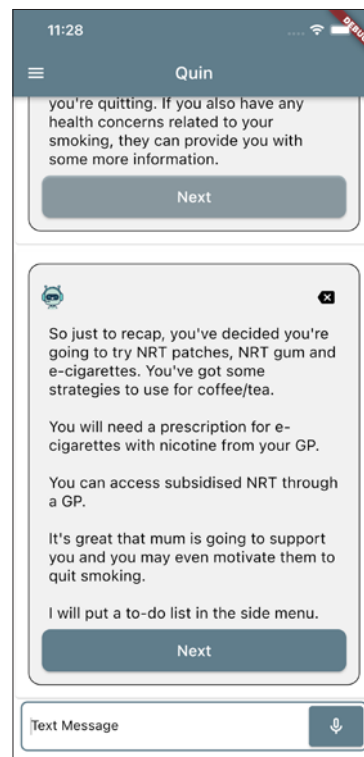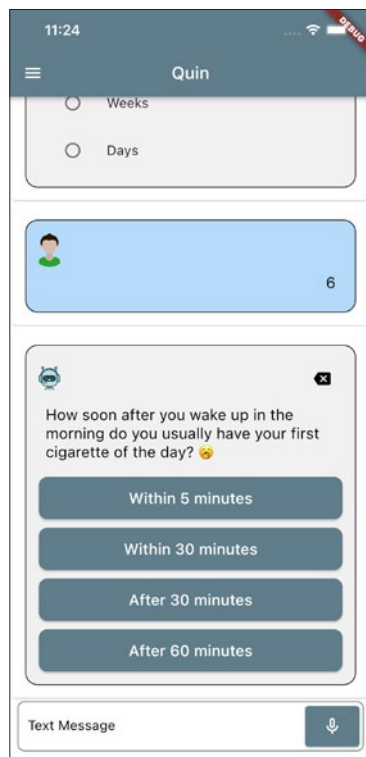
Example dialogues with Quin asking how soon smokes after waking up; Quin providing a recap of the persons quitting strategy and Quin computing how much money the user could save by quitting smoking.

Aurora: Sleep dependent memory chatbot

Collaborator: University of Sydney

A body of evidence supports the notion that sleep contributes to memory consolidation. Despite these findings, sleep-dependent memory is not routinely studied particularly in people living with mild cognitive impairment. Aurora is a chatbot that administers a sleep-dependent word-pair memory test developed at the University of Sydney for people living with mild cognitive impairment.

Aurora sets up a user profile, provides instructions to the user, and display the word-pairs widget within the valid time window. She also coordinates scheduling of notifications and procedures when a missed appointment has occurred. Two focus groups were run by University of Sydney with participants from the Healthy Brain Ageing reference group. Focus group participants raised no issues with the layout and design in the screenshots provided. Aurora will soon be used in several pilot studies.
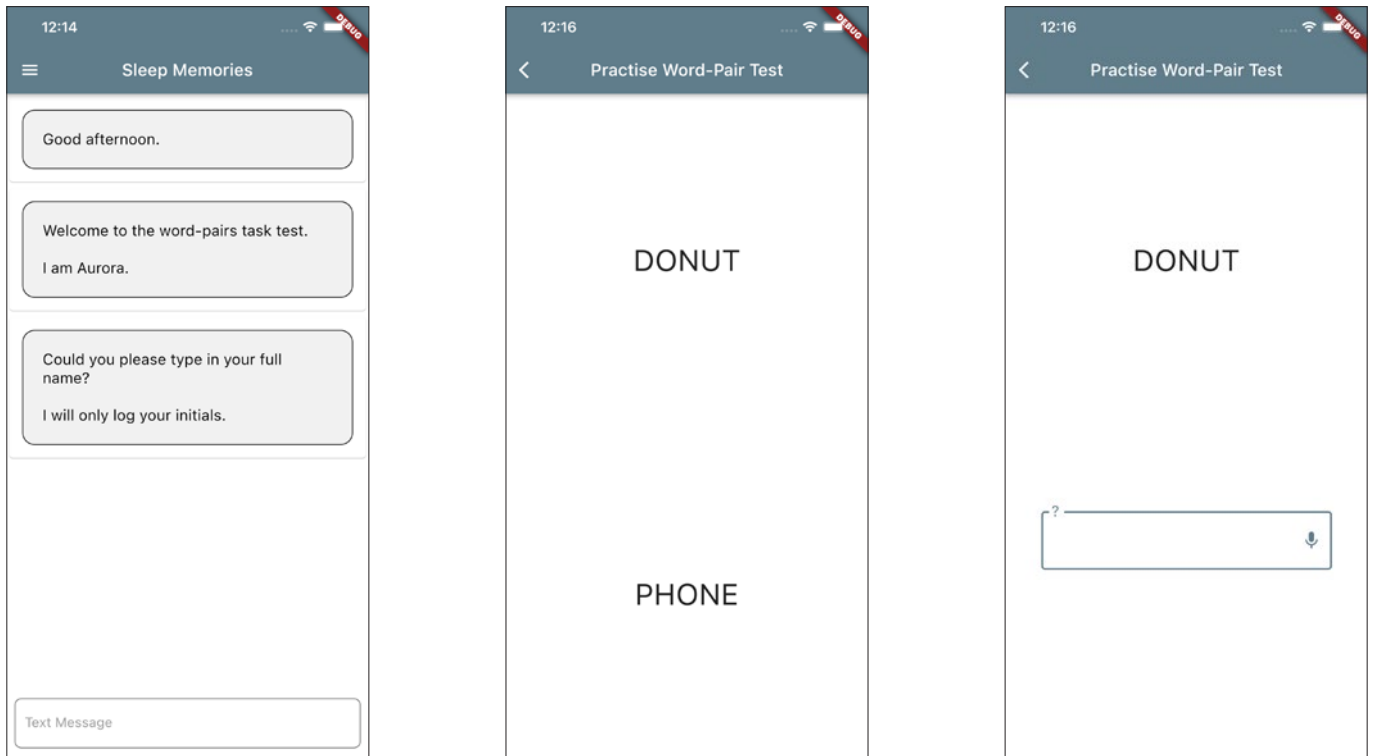
Screenshots of the Aurora chatbot introducing herself and example word pairs that the use is asked to memorise and recall before and after sleeping.

Health Data Semantics and Interoperability: postdoc and student highlights

Postdoctoral fellows

Yutong Wu, CSIRO Research+ Postdoctoral Fellowship

Clinical information extraction and classification using interpretable deep learning

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

In this research, revolutionary interpretable deep learning algorithms have been developed to automatically extract and classify clinical information from both unstructured clinical notes and structured data sources. These approaches scale to large amounts of data and 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.

Yen Pham, CSIRO Research+ Postdoctoral Fellowship

Representing and simulating a complex One-Health system of AMR infections and drivers using system dynamics

Unravelling complex human, animal, and environmental interrelationships that underpin the 'wicked' antimicrobial resistance (AMR) problem is critical for curbing AMR. Systems dynamic modelling approaches, within a One-Health data-rich ecosystem, will be investigated to create an evidence-base of novel drivers that will help explain pathways of AMR transmission and evolution. This will improve our understanding of how these drivers interact within the complex system of AMR infections and facilitate the formulation of new interventions and policies for curbing AMR.

Filip Rusak, CSIRO Research+ Postdoctoral Fellowship

Personalised antibiotic stewardship

Antibiotic choices for treating many bacterial infections are becoming limited and, in some cases, non-existent. Inappropriate prescribing has been a key factor. Personalised decision support technologies using artificial intelligence and data science methodologies that leverage large-scale, state-wide electronic health records for profiling cohort AMR exposures will be investigated to enhance the precision of antibiotic treatment. Optimising the use of antibiotics is of core importance for mitigating antimicrobial resistance (AMR).

Shengyao Zhuang, CSIRO Research+ Postdoctoral Fellowship

AI-driven search engine technology

LLMs like ChatGPT stand to have a huge impact on how people seek and consume information. Shengyao's research is developing novel models and applications of LLMs in the health space. He has shown how these general purpose, foundational models can be tailored to answering clinical questions, without the need for vast amounts of training data required for previous approaches. While making core scientific contribution to search engine research, he is also applying helping to achieve real impact by translating his research to the specific project to precision medicine search for paediatric oncology.

Bing Liu, CSIRO Research+ Postdoctoral Fellowship

AI-driven natural language processing for precision medicine

Precision medicine is all about identifying relevant treatments tailored to the needs of individual patients. But an ever-growing body of medical literature and clinical trials makes sifting through all this information a real challenge. Bing's research involves developing AI methods to identify genes, drugs and diseases from the myriad of information now available to clinicians. He has built an efficient and effective natural language processing pipeline capable of extracting key information needed by clinicians to find targeted treatments for their patients. This pipeline forms the backbone of the team's project to develop a specialist precision medicine search engine for paediatric oncology.

PhD students

Liebo Liu, UNSW – CSIRO Industry PhD

Extracting value from unstructured health data

This research applies NLP technologies, including machine learning methods for named entity recognition (NER), to extract structured clinical information from narrative text. The emphasis is on developing tools to reduce waste and duplication and drive high-value healthcare.

Jinghui Liu, CSIRO R+ Postgraduate Scholarship University of Melbourne

Unlocking EHRs 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. NLP and ML models will be used to identify concepts from clinical text for the purposes of phenotyping and identifying patient cohorts. The overall goal of the project is to build systems able to process large corpora of clinical text to help clinicians use existing knowledge and aggregated patient data to develop personalised treatment and prevention plans.

The Transformational Bioinformatics group

Group Leader:
Dr Denis Bauer

The Transformational Bioinformatics group enables scientists and industry partners to scale their research output using cloud-computing and machine learning. The group delivers impact in two areas: human health and biosecurity.

Transformational Bioinformatics' science and impact highlights for 2022/23

- Nature Biotechnology paper (IF=68, accepted) about the world's first query engine for genomic and medical data, which scales to millions of patient samples. This enables genomics consortia around the world to share their data more efficiently and support clinicians to make diagnoses with more comprehensive data especially in currently underrepresented population groups.

- We continue to support newborn screening and neonatal testing in Australia through our engagements with NSW Health, Westmead Children's Hospital, as well as GenePath and Sydney University.

- Together with UTS and ANU, we secured grant funding for RNA innovation (therapeutics and vaccine) to establish a national digital platform for RNA design.

- Natalie was awarded Brilliant Women in Digital Health, Rosa Prahl completed a Graduate Certificate in Management from the Australian Institute of Business and Laurence finished a Graduate Diploma in Data Science from UNSW.

Genome Insights

Team Leader: Dr Natalie Twine

**Acting Team Leader
(Jan 2023 – Oct 2023):
Dr Letitia Sng**

The Genome Insights team generates knowledge into genome-trait relations by analysing population-scale 'omics (genomics, transcriptomics, proteomics) and integrating with observational data. Our aim is to discover the genetic origins of disease and ultimately improve diagnostics and design new treatments. Our software solutions also facilitate the incorporation of genomic information into clinical practice via 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. By computationally guiding editing machinery, such as CRISPR-Cas9, we improve accuracy and efficiency, and enable applications in human health (for example in genetic surgery and gene therapy or lab-free at-home diagnostics for genetic or infectious diseases) and biosecurity (in areas such as the genetic control of invasive and dangerous species).

Bioinformatics Products

Team Leader: Yatish Jain

The Bioinformatics Products team leverages cloud technologies and machine learning approaches to develop innovative bioinformatics platforms and novel algorithms in the health and biosecurity domain. Sustainable software development not only facilitates reproducible research but also opens commercialisation possibilities. The team builds sustainable bioinformatics solutions and distributes them using various delivery vehicles such as infrastructure as a code, web interfaces, cloud marketplaces and federated APIs to reach broader bioinformatics communities.

Transformational Bioinformatics: platform technologies

VariantSpark

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

Our genomes hold information that can substantially improve clinical care. However, reading this information and linking it to function is challenging. While genome wide association studies (GWAS) have identified individual genetic contributors to diseases and traits (biomarkers), and polygenic risk scores (PRS) capture the overall genetic disease risk, there is no methodology able to identify the set of specific biomarkers that capture contributions from individual genes as well as the interaction between genes to predict overall disease risk. VariantSpark provides this capability, thereby improving clinical care while also increasing knowledge of the molecular mechanisms of disease.

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 with 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 within health. VariantSpark is available for high-performance compute clusters (HPC), as well as for cloud computing, through services such as RONIN, AWS, Azure, and TerraBio.

Over the last 12 months, we have analysed the world's largest genomic data repository (UKBiobank) using Alzheimer's disease (AD) and cardiovascular disease (CVD) phenotypes. We subsequently performed validation analysis using the NIH TopMed datasets (CVD) and

Alzheimer's Disease Neuroimaging Initiative (ADNI) cohorts. Crucially we have developed and published a novel significance testing methodology for VariantSpark, which enables prioritisation of disease associated variants and controls the false positive rate (Computational and Structural Biotechnology Journal, under review). Our work made the ground-breaking observation that VariantSpark captures more genetic variance in the UKBiobank and ADNI cohorts than is possible with traditional logistic regression methodology (PLINK).

We further developed an ecosystem of open-source software around VariantSpark, such as BitEpi (SciRep, 2021) which uncovers the interacting genes from the VariantSpark output and visualises them in their biological context, as well as PEPS (Medinfo 2023) to create realistic synthetic datasets. Speaking to the application agnostic capability of VariantSpark, we applied it to find COVID-19 viral mutations associated with worse disease outcomes (published in Computational and Structural Biotechnology Journal, 2022).

Serverless Beacon

Collaborators: UMCCR, MGHA, DFAT, and GISlab, Indonesia, Australian BioCommons

Data sharing in genomics is a crucial yet challenging task. The sheer volume of genomic data increases every day with application for researchers, clinicians, and pharmaceutical organisations, e.g. cohort studies, diagnostics, and drug discovery. sBeacon implements the Beacon V2 protocol by GA4GH which facilitates federated data exchange by introducing a venue to search for genomic and phenotypic data subjected to different constraints defined using ontology terms. sBeacon pushes the envelope of capabilities available in reference implementations producing a beacon with far greater potential while maintaining better performance at a fraction of the cost.

VariantSpark can process both big and 'wide' genomic data to drive biological insights.
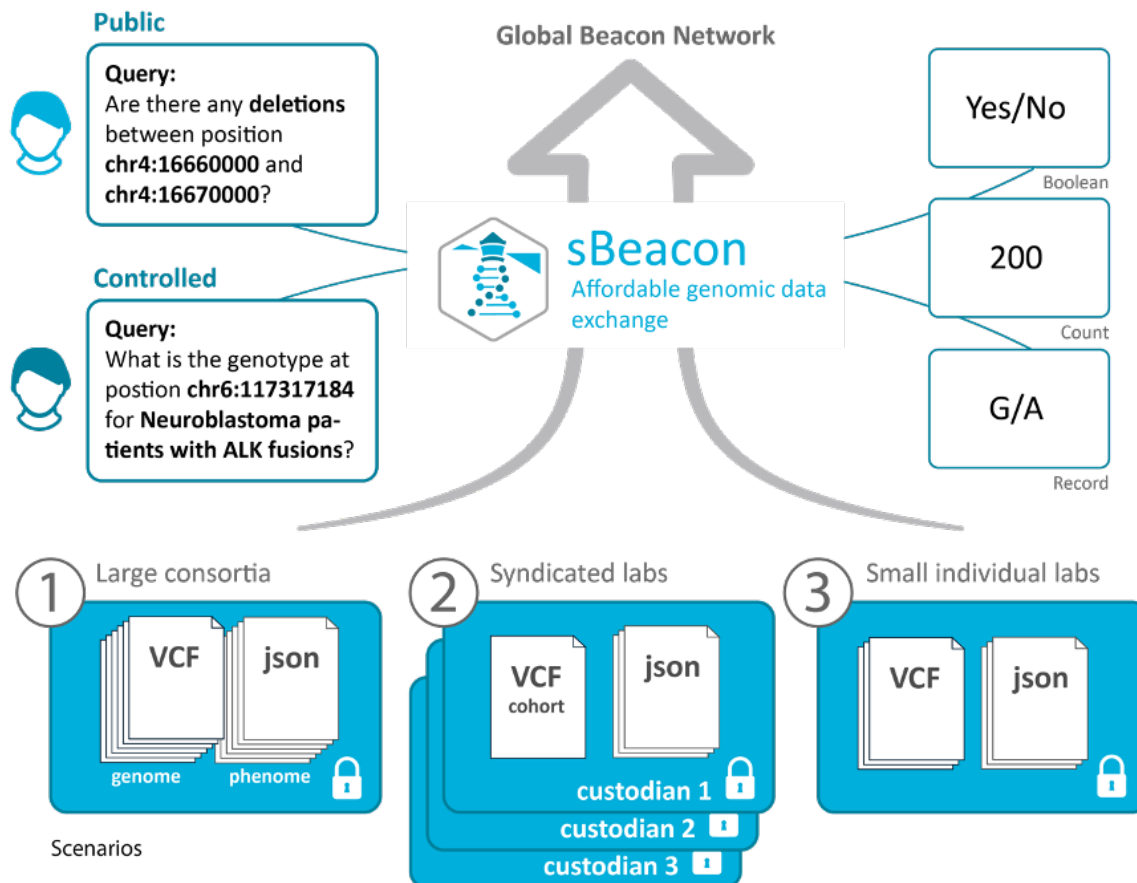
Serverless Beacon allows fast and economical exchange of genomic and metadata while enabling data custodians to regulate data access.

sBeacon is implemented on top of popular AWS technologies such as AWS Lambda, DynamoDB, S3, and Athena. All these technologies are delivered in a serverless form which eliminates idle time costs associated with infrastructure maintenance. Furthermore, this enables sBeacon to scale on demand and maintain high performance without having to manage any aspect of scalability. Moreover, sBeacon integrates with CSIRO's Ontoserver to perform indexing required for complex ontologies queries that can generate useful insights into genomic and phenotypic relations. The novel architecture of data storage mechanism of sBeacon allows users to run complex queries that involve multiple parameters across different metadata entries which is not available through any reference implementation.

This year, sBeacon has been accepted at Nature Biotechnology (IF 68) and has found application at UMCCR's Human Genome Platform Project to share and query genome data, as well as GSIlab, Indonesia's second-largest sequencing facility to achieve great scalability for continuous pathogen monitoring. We are currently developing sBeacon's pathogen domain further into PathsBeacon, which enables the rapid detection and tracking of specific pathogen strains.

GT-Scan Suite

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

GT-scan is a platform solution that improves the accuracy of genome engineering applications (on-target scoring, SNP-aware off-target search) to enable novel high-precision applications such as human health. Finding a suitable genome editing spot is like finding a specific grain of sand on the beach; it needs to have the right shape and colour (properties for CRISPR to bind) and 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 Function-as-a-Service or serverless. We have continued to expand the capability of the platform, working with collaborators at the University of Adelaide to develop analysis pipelines for new and emerging gene editing technologies (such as our PETAL tool for designing prime-editing applications) and targeting diverse populations (e.g. our VARSCOT2.0 pipeline).

Over the past years, we established a cloud-based computational framework for designing a wide range of CRISPR-based experiments. This platform is comprised of several published tools including GOANA (evaluation framework for gene-editing experiments), TUSCAN (CRISPR-Cas9 on-target efficiency predictor), CUNE (efficiency and effect predictor for HDR-based editing) and VARSCOT (SNP-aware off-target finder). Our work led to a review on CRISPR-Cas9 predictive tools (cited over 90 times) and has been presented at many international conferences. Read more in Transformational Bioinformatics: Project Updates.

Serverless INSIDER

Collaborators: Kieran Didi (https://github.com/kierandidi)

Detection of foreign DNA and mobile genetic elements in a pool of genomic sequences or a single genome is vital in biosecurity applications such as gene drive detection and in pursuit of anti-microbial resistant plasmids, which we demonstrated in our *Computational and Structural Biotechnology* journal paper in 2021. Serverless INSIDER (sINSIDER) adapts INSIDER for cloud computing decreased cost and compute efficiency. For this we pioneered a new way of standing up a serverless way of running Apache Spark on AWS utilising EMR clusters. The infrastructure pattern was developed as a terraform module and published in the global terraform registry to support the IT community to stand up similar infrastructures for health and non-health domains (https://registry.terraform.io/modules/kierandidi/emrserverless/aws/1.0.0)

We optimised the INSIDER pipeline for AWS EMR serverless infrastructure by limiting IO operations and in-memory data frame passing (https://bitbucket.csiro.au/projects/SERVERLESS-INSIDER/repos/serverless-insider/browse). sINSIDER is available through a web server to make the pipeline more accessible to the researchers. The website was developed using the Angular web framework and the backend was developed using AWS Lambda service. We also used DynamoDB to handle the job submission and tracking aspects of the pipeline (https://bitbucket.csiro.au/projects/SERVERLESS-INSIDER/repos/insider-website/browse).

The end-product, sINSIDER is available at gt-scan.csiro.au/sinsider and available to the public with minor restrictions for security reasons.

Transformational Bioinformatics: project reports

Serverless Beacon

Collaborators: UMCCR, MGHA, DFAT, and GSIlab, MoH Indonesia, Australian BioCommons

sBeacon implements the GA4GH Beacon protocol V2 in a serverless manner on the AWS cloud provider. sBeacon is currently being explored by the University of Melbourne Centre for Cancer Research (UMCCR) to cater to their data querying and exchange requirements. sBeacon allows our collaborators to query multiple dimensions involving genomic and phenotypic information. Furthermore, sBeacon integrates CSIRO's Ontoserver to facilitate complex metadata querying needed to generate actionable insights into data.

sBeacon was initially developed using the Beacon protocol V1 and the development of V2 sBeacon began in early July 2022. We were able to implement the complete Beacon V2 protocol specification in the serverless environment during the last year. Furthermore, we tested sBeacon at a population scale of 100000, 1 million, and 40 million individuals. We demonstrated that sBeacon can perform robustly by scaling up to a population level dataset while maintaining zero idle compute costs and smaller querying costs and time.

sBeacon has been implemented using various AWS services, including Lambda, DynamoDB, Athena, and S3. The platform optimises parallelism, speed, and cost efficiency by distributing queries across VCF files and base ranges. To enhance its capabilities with medical ontologies, sBeacon utilises Ontoserver to index terms from SNOMED, streamlining hierarchical queries. Additionally, sBeacon supports the Ensembl OLS terminology service, which is widely adopted within the community. This versatile platform can ingest both genomic and phenotypic data. Genomic data can be ingested and registered without duplicating sensitive and storage intensive VCF files. On the other hand, phenotypic data follows a well-defined schema for ingestion, and there are plans to expand this capability in the future using FHIR objects.

sBeacon's acceptance for publication in the prestigious *Nature Biotechnology* journal, known for its extensive research outreach and impressive impact factor of 68, is a testament to its significance in the field. This ground-breaking platform opens up exciting new possibilities for researchers, as it enables faster and more cost-effective complex queries, a feature not found in other reference beacon implementations.

One of sBeacon's most appealing aspects is its deployment simplicity and minimal running costs, making it an attractive and feasible option for smaller labs as well as large consortia. Additionally, its ability to be deployed on AWS offers the advantage of meeting privacy requirements in different regions, thanks to the multitude of availability zones and regions provided by AWS. Overall, sBeacon stands out as an innovative and accessible solution with far-reaching benefits for the genomics research community.

Dynamic consent and Indigenous populations

Collaborators: Sydney Children Hospital, NSW Health. NSW Pathology, Telethon Kids Institute, National Centre for Indigenous Studies

The dynamic informed consent model is an innovative approach to managing consent in genomics and healthcare. It prioritises continuous engagement and flexible participation of individuals who volunteer their data, while respecting their cultural values and social beliefs. This is particularly important in, for example, Indigenous communities, where the cultural connection to genetic heritage is distinctive from the Western understanding of genomic information. The model empowers individuals by granting them control over their personal genomic information. This concept, supported by diverse genomic professionals in recent studies [Yuwan et al, 2023], emphasises that individuals or their rightful representatives should have the authority to decide who can access their genomic data.

Our implementation of the dynamic consent model follows a participant-centric design based on the principles of self-sovereign identity (SSI). In this model, participants' identity and information credentials are stored in verifiable credentials as payload with a digital signature for proofs. These credentials also include consent states, indicating participants' preferences for the use of their genomic and health data in different scenarios. We store these consent states in an immutable ledger, ensuring tamper-proof recording with cryptographically verifiable records. The consent states are based on GA4GH's DUO ontology terms, describing various data use terminologies.

Collaborating with Children's Hospital Westmead and NSW Health Pathology, we are developing the dynamic consent management system using infrastructure-as-code in a *serverless* manner for cost-effectiveness for the TRAIL newborn screening project funded by the Medical Research Future Fund. To manage data volunteers' identity and credentials, we employ CSIRO's MacroKey digital wallet, implementing a password-less decentralised approach for user identification. Our backend is developed using different AWS services such as S3, AWS Quantum Ledger database (QLDB), AWS Cognito, and AWS Lambda. Adopting a decentralised approach to consent management increases trust and participation of individuals in genomics and health studies.
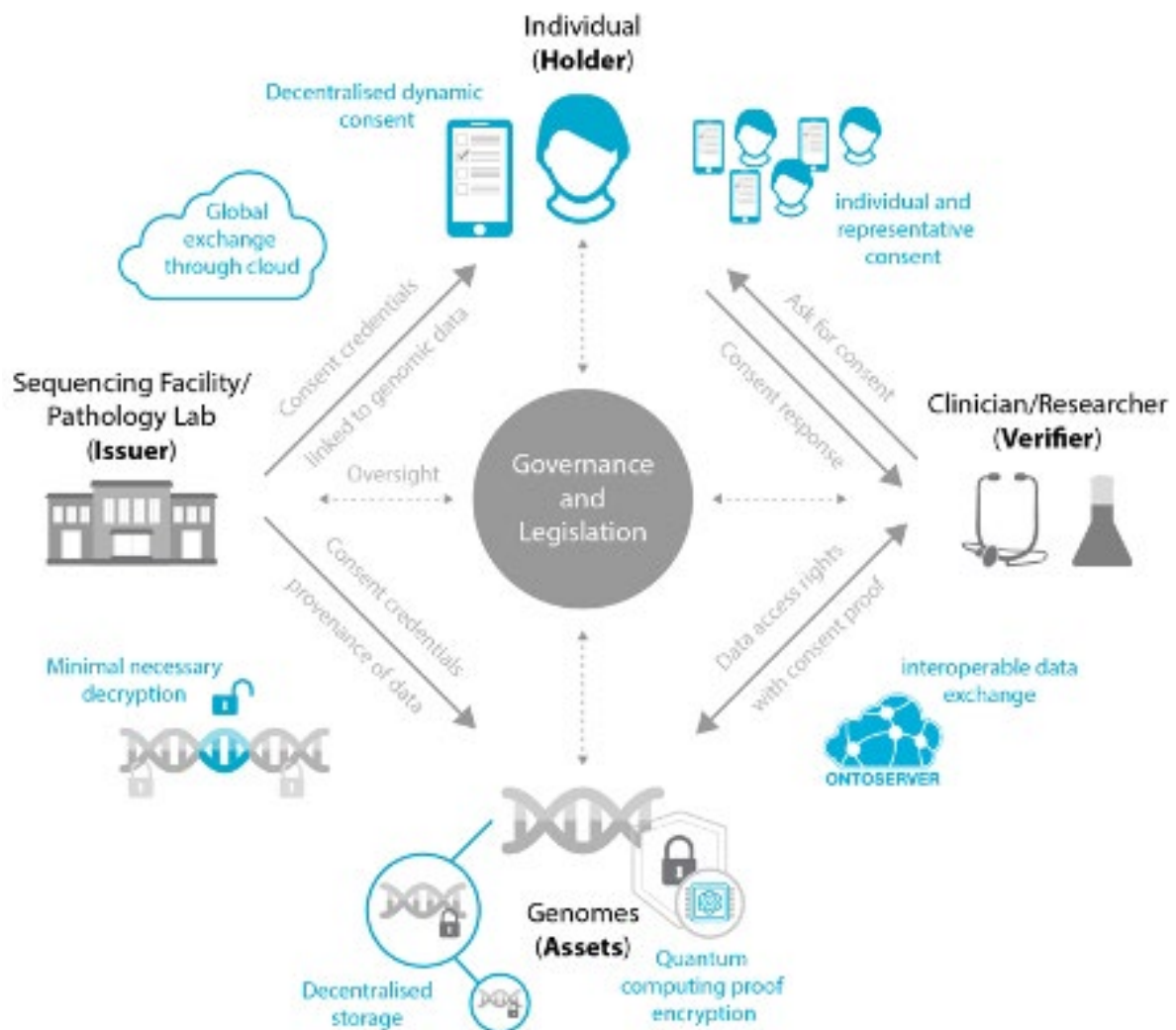
A trust model using the self-sovereign identity framework to enable participant-controlled consent management in genomics.
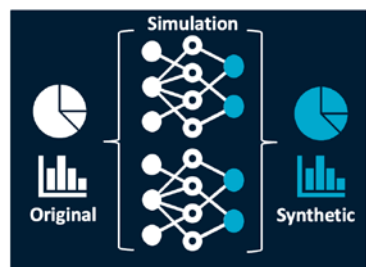
Synthetic data and PEPS

Collaborators: CSIRO eHealth initiatives and the Royal College of Pathologists of Australasia

Synthetic data is increasingly prevalent due to its versatility and low generation cost. Specifically, current regulations make it difficult to share healthcare data and novel acquisition is costly in time and money. In contrast, synthetic data can overcome these issues as artificially generated data can retain the structure and patterns while protecting the individual's patient privacy.

We are using AI to artificially generate lifelong patient medical records. Our project relies primarily on deep learning, particularly generative adversarial networks (GANs) and diffusion models. As a backbone model, we developed a temporal GAN which learns the temporal disease order from the training dataset and reproduces the same patterns and statistical similarities in the synthetic data. Based on the information generated we aim to append different data types. For example, we can generate chest X-rays for a variety of diseases observable through this means using a diffusion model. In addition, we have been on the frontline efforts of synthetic genomes generation and synthetic epistatic phenotypes. We developed a synthetic genome generation that is highly scalable and retains mutation correlations (linkage disequilibrium) while we incorporate synthetic phenotypes.

This project has piqued interests of national (Queensland Health and the Royal College of Pathologists of Australasia) and international (BCB medical, FinnGen) collaborators. This initiative has already produced two research publications and hired a new post-grad student to generate more research outcomes.

Synthetic data generation is made by learning the patterns from real-world data.

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

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

Since 2020, the COVID-19 pandemic has been a global health concern with worldwide cases recording over 500 million, with 6 million deaths. Vaccines cannot prevent all infections and the emergence of new COVID-19 variants of concern has complicated vaccine development. Safe, effective, and affordable COVID-19 treatment is vital in the pandemic response, especially for 'long-COVID'. This project is led by CSIRO's Centre for Disease Preparedness (ACDP), in collaboration with multiple CSIRO Business Units, Deakin University/Barwon Health, and UNSW School of Mathematics and Statistics.

The drug selection committee identified several TGA/FDA approved drug-candidates for use which have been used in *ex vivo* and *in vivo* studies. Current stages of the project involve the overarching machine learning task to identify important regulatory features through random forests. Random forests are suitable for complex datasets and enable the extraction of important features. Over the last 12 months, we have had a steady output of multi-omics data (transcriptomics, proteomics, lipidomics, and metabolomics) across the project activities. These ML methods will be applied to identify multiple features contributing to *ex vivo* disease progression, vaccine efficacy or treatment (drug) response.

The outcomes of this project will be implemented for 'Disease X' treatment and will allow for a better correlation between *in vivo* models of COVID-19 (e.g., ferrets) by comparison to *ex vivo* models involving relative tissue types and human observation studies.

This project is funded by the Australian Government's Medical Research Future Fund, and internal CSIRO funding.
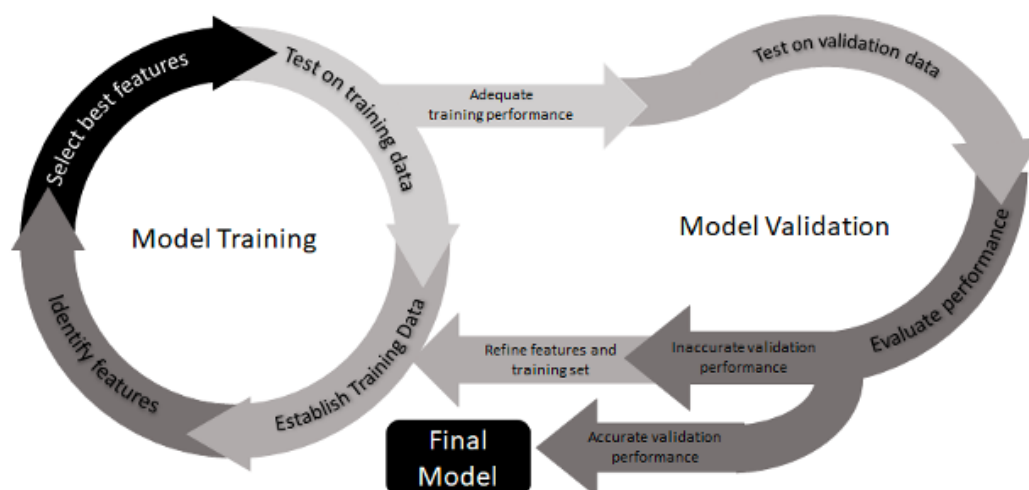
**Machine learning method to identify treatment progression and efficacy**

Gene drive platform

Collaborators: Australian Pest Genome Alliance

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

We have developed platforms that can analyse diverse populations to design complex and targeted intervention strategies. Our platform, VARSCOT2.0, builds upon our original VARSCOT pipeline which was the first tool for designing gene editing approaches that takes into account an individual's unique genomic profile (Figure). We have now expanded the pipeline to handle population level information in a high-throughput manner using AWS cloud computing. In addition to identifying drives common within a target population, the platform can also analyse the genome of bystander populations reducing the risk of the drive spreading beyond its intended targets. The platform will integrate with the GUARD pipeline being developed by the Australian Pest Genome Alliance, which is used to model the effectiveness of potential guides, providing researchers and policy makers with an end-to-end platform for the design and evaluation of targeted drives.

Using these new tools, we have begun working with other researchers within CSIRO to begin designing targeted intervention strategies to tackle the problem of invasive species and anti-microbial resistance.
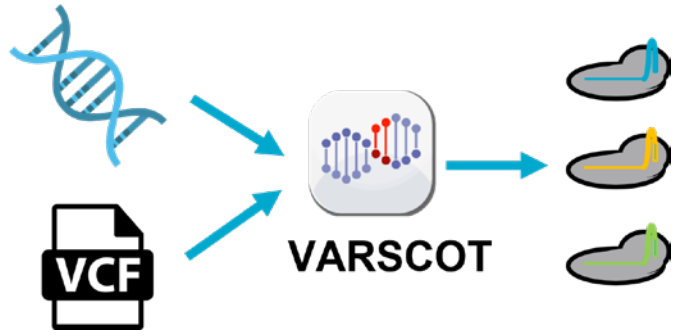
Our new gene drive platform builds upon our VARSCOT platform to analyse the genetic variance within a population (stored in a VCF file) to identify strategies to target the entire population.

CSIRO's diagnostics

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

The gene editing CRISPR-Cas technology was ground-breaking, allowing researchers to directly modify the DNA of living cells. It has enabled breakthroughs in the fields of precision health, biosecurity and agriculture and led to an explosion of new technologies building upon the original CRISPR-Cas9 system. The aim of the CRISPR-APAIR project is to evaluate these different methods across different plants and animals to identify the most optimal editing strategy for CSIRO. Our contribution to the project has been the development of high-throughput pipelines for the design, evaluation, and analysis of these experiments. Building on our GT-Scan suite, we have created algorithms for evaluating the effectiveness of these strategies, which have reduced research time and resources. These approaches can compare multiple diverse populations to identify strategies which are highly selective and discriminatory, ensuring that only the target species is diagnosed.
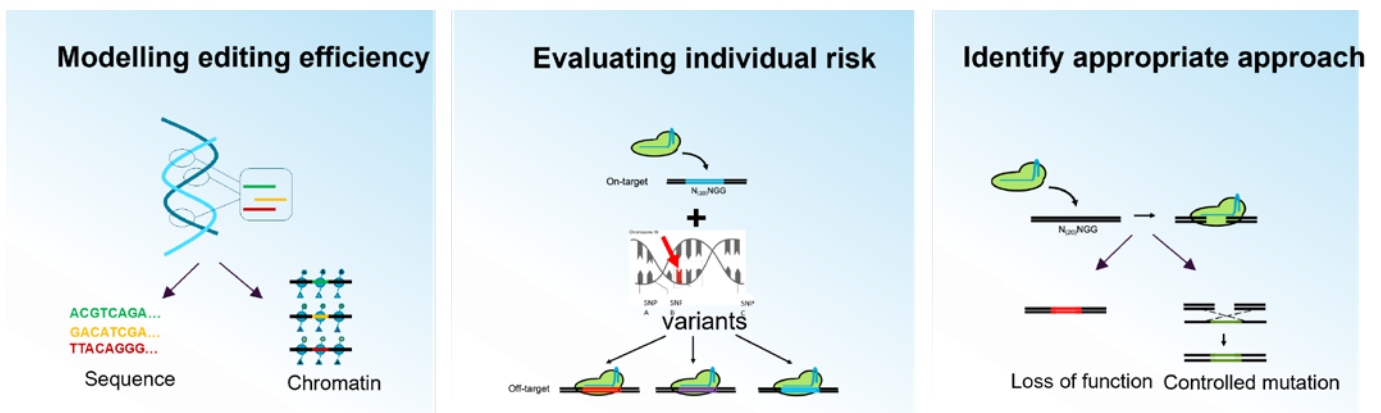
The GT-Scan suite contains a collection of tools which simplifies the design and analysis of genome editing experiments.

GenePath newborn screening new paper

Collaborators: GenePath, Pathology QLD,
Monash University

Newborn screening (NBS) programs is a successful public health initiative that has resulted in improved health outcomes for thousands of children. The current NBS screening protocol (also known as the heel prick test) screens for up to 25 rare childhood conditions, even though there are over 600 conditions with available treatments, mainly due to technological limitations of biochemical and molecular genetic tests. Next generation sequencing (NGS) is eagerly anticipated as the next step to expand NBS programs. GenePath, an Australian start-up, in collaboration with QLD Health and CSIRO has demonstrated that NGS is a cost-effective approach that can be incorporated into NBS programs to increase the number of conditions screened.

Specifically, NGS data from a whole of population sample of 2,552 newborns in Queensland were analysed. Key results include (1) evidence that individuals of European ancestry would be least likely (1.63%) to have genetic variants of unknown disease significance reported, while individuals of East Asian (2.38%) and African (3.46%) ancestry are more likely, (2) based on the NGS gene panel, the allele frequency in the Queensland 2,552 dataset, and an annual birth rate of ~60,000 births for Queensland, 695 individuals were projected to be screened positive for a condition annually, and (3) using a 164 gene panel to screen 60,000 newborns a year would result in a cost per positive screen of ~USD5,262 whereas the introduction of molecular genetic tests for SCID and SMA would cost ~USD92,400.
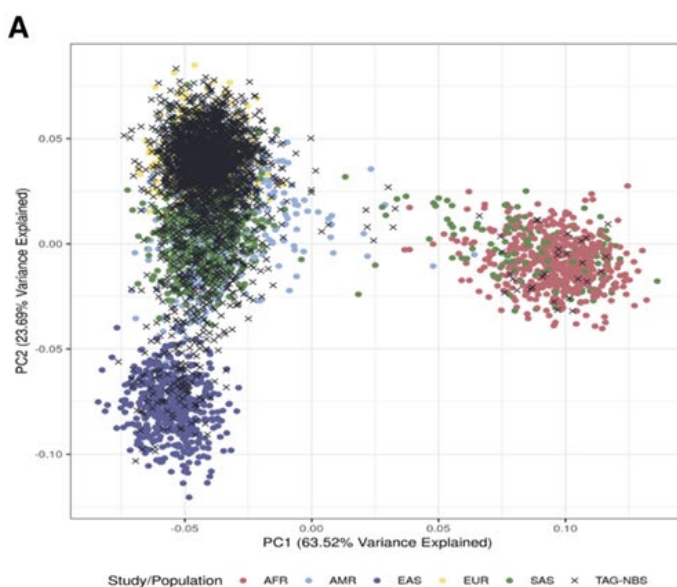
Transformational Bioinformatics: project updates

Machine learning variant prioritisation platform

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

Whole genome sequencing is crucial for diagnosing rare inherited diseases, but diagnostic rates remain low due to infrequent reanalysis. The automated reanalysis project will develop a sustainable program for the systematic reanalysis of genomic data using scalable cloud-based systems and an ML algorithm to prioritise disease-causing variants.

Our collaborators have produced a reanalysis pipeline to identify high confidence pathogenic variants in undiagnosed rare disease patients. We are working on a novel ML tool to enhance this pipeline. The tool focuses specifically on the diagnostic challenge presented by missense variants, characterised by their complex nature and diverse effects. We trained a random forest model to predict pathogenic variants using genomic data from clinically reported cases. The model incorporates allele frequency, pathogenicity scores, and conservation scores as features and has a robust performance (precision=0.971, recall=0.973). Future iterations of the algorithm intend to enhance its capabilities by incorporating patient phenotypes and 3D protein modelling.
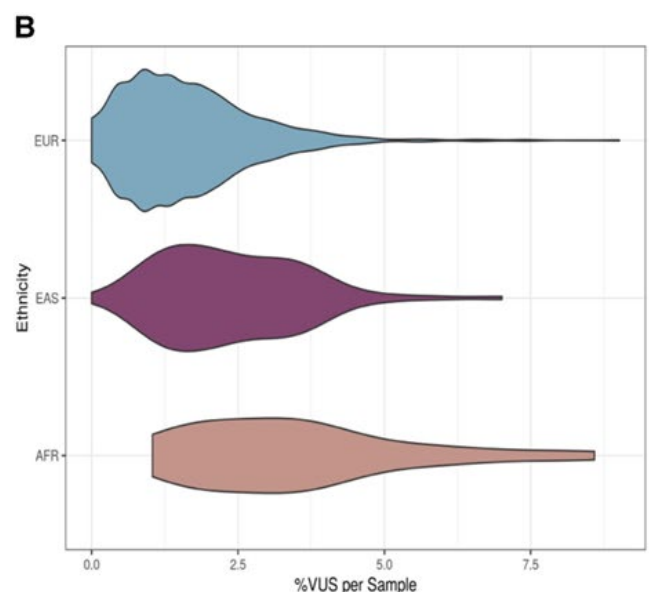
Genetic distribution of study cohort compared to the 1000 genome projects ethnicities and percentage of genetic variants of unknown disease significance per sample stratified by estimated ethnicity.

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

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

Gene-gene interactions, or epistasis, are proposed as part of the solution to the missing heritability problem in genomics. For example, the cumulative heritability of known genetic variants for coronary artery disease is 28%. VariantSpark is a cloud-based machine learning platform that accounts for both marginal and epistatic effects of genotype associations to complex phenotypes. An exciting new extension of our VariantSpark platform is the RFlocalFDR, which enables the identification of significant associations, overcoming the challenge of attributing statistical significance to variable importance scores. Significant associations are then fed into BitEpi, our tool that identifies higher-order epistatic interactions, creating a complete genome-wide association study and epistasis analysis pipeline. We have applied this pipeline to identify novel genes and genetic mutation markers associated with two complex diseases, Alzheimer's disease (AD) and coronary artery disease using the UKBiobank, which contains genotype and phenotype information from up to 500,000 samples as a discovery dataset.

Validating our results with the Alzheimer's Disease Neuroimaging Initiative cohort, we have found two novel genes associated with AD through an epistatic interaction involving the well-known AD-causing gene, APOE. The calculated variance explained for the UKBiobank cohort was shown to increase with the inclusion of BitEpi interactions indicating that epistasis does indeed play a role in AD. Similarly, we have validated well-known coronary artery disease genes in the Trans-omic for Precision Medicine (TOPMed) cohort using VariantSpark. Using BitEpi, there is evidence of epistasis between these two genes where one may be affecting the other in a trans-mediated fashion through an alu-motif.

Viral capsid modelling

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

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

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

Pathogen genomics pipeline for viral evolution

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

Wildlife-livestock interactions have increased over the last century with a shift in parasitic to viral disease studies due to improving technologies. Changes in the environment and human behaviour increases the risk of zoonotic infections emerging from wildlife and severely impacting the health and economy of our community. Viruses also undergo evolution via mutations as part of host-pathogen interactions impacting disease progression, treatment resistance and vaccine development. We improved upon an existing pipeline in efficiency and scope, allowing for a broader application applying different viruses to search and track mutations of interest *in situ* from a given dataset. This can be used with our tool using association rule mining to find pairs/groups of sites that contribute to the overall fitness of the virus. In combination, these tools can identify significant mutations of interest for surveillance.

Vaccine design

Collaborators: Minimising Antimicrobial
Resistance Mission, UTS

Designing new vaccines is a complex, time consuming and expensive process, typically taking 10-15 years from initiation to clinical application. To address this, we are working with collaborators within CSIRO and externally to develop new computational methods to the streamline the process, helping researchers predict the best vaccine targets for effective intervention. This project uses ML and protein structure modelling to simulate how pathogen antigens interact with the immune receptors and predict the antigen sequences that are most likely to elicit a strong immune response. In addition to developing these new methods, we are also working to apply these methods to assist in the development of new vaccines for biosecurity threats including African swine fever and drug resistant bacteria.

ACORN 2023 GPU acceleration of SARS-CoV-2 analysis pipeline

GPUs show promise in accelerating certain workloads that can be massively parallelised by virtue of the increased number of compute units when compared to CPUs. It's therefore worth considering GPUs as a potential replacement for CPUs in our bioinformatics pipelines, especially those that work over large amounts of data.

An antimicrobial resistance pipeline was built using CPU-based tools, and used as a case-study in GPU acceleration. Only one component of the pipeline, medaka, contained support for GPU acceleration, and that component did not run for a large enough percentage of the pipeline to make up for the 3x increase in cost for a GPU-enabled EC2 instance. For now, cloud GPUs are too expensive for most cpu-based pipelines to experience a cost benefit from switching to GPUs. An accelerated pipeline should be built from the beginning to utilise GPUs and, where possible, use GPUs that are already present in CSIRO infrastructure.

Optimised compute architecture for RNA/DNA modelling

Collaborators: CSIRO's IMT

DNA/RNA modelling is a powerful tool for understanding molecular dynamics and is critical to many of our research projects. In particular, we use it to understand how protein vectors can deliver therapeutic cargo for gene therapy applications. Accurate modelling of the 3-dimensional structure of these vectors is critical. Currently, the gold-standard for modelling protein dynamics is nanoscale molecular dynamics (NAMD) (https://www.ks.uiuc.edu/Research/namd/documentation.html). NAMD can model the classical Newtonian dynamics of systems with hundreds of thousands to millions of particles, explaining that the computational requirements for running NAMD simulations can be quite high, depending on the size and complexity of the system being modelled. While NAMD is designed to be highly parallel, achieving good parallel efficiency (i.e., effectively using all available CPUs or GPUs) can sometimes be challenging, particularly for smaller systems or for systems that do not evenly divide across the available processors. The aim of this project is to optimise the deployment of NAMD on CSIRO HPC architecture.

Solid Pods

Collaborators: CSIRO's Data61, Australian
National University (ANU)

Solids PODS (personal online data stores) (https://solidproject.org/) refer to infrastructure/architecture that consists of solid servers and solid pods. Solid servers host one or more pods, and pods provide storage space for different users, with the infrastructure being managed by the pods provider. Users can control the content in a pod and can grant access to different content in their pods using an access control mechanism. Due to the fully decentralised nature of control provided by the pods, they hold immense potential in the management of personal health data and engagement in various clinical and research activities.

As a preliminary study to evaluate the feasibility of genomic applications, we conducted a comprehensive examination of the authentication and authorisation mechanisms facilitated by pods. Currently, pods SDKs are provided by Inrupt.com. The SDK can be used in applications referred to as solid apps. It provides three modes of authentication: web-based authentication, server-side authentication with a web login window, and static app registration. For genomics-related tasks, we identified static registration to be more appropriate, as other approaches have session tokens that expire in short intervals. However, static registration of solid apps is not widely available, and the approach provided unprecedented access to data with little to no control over access (read, write, append).
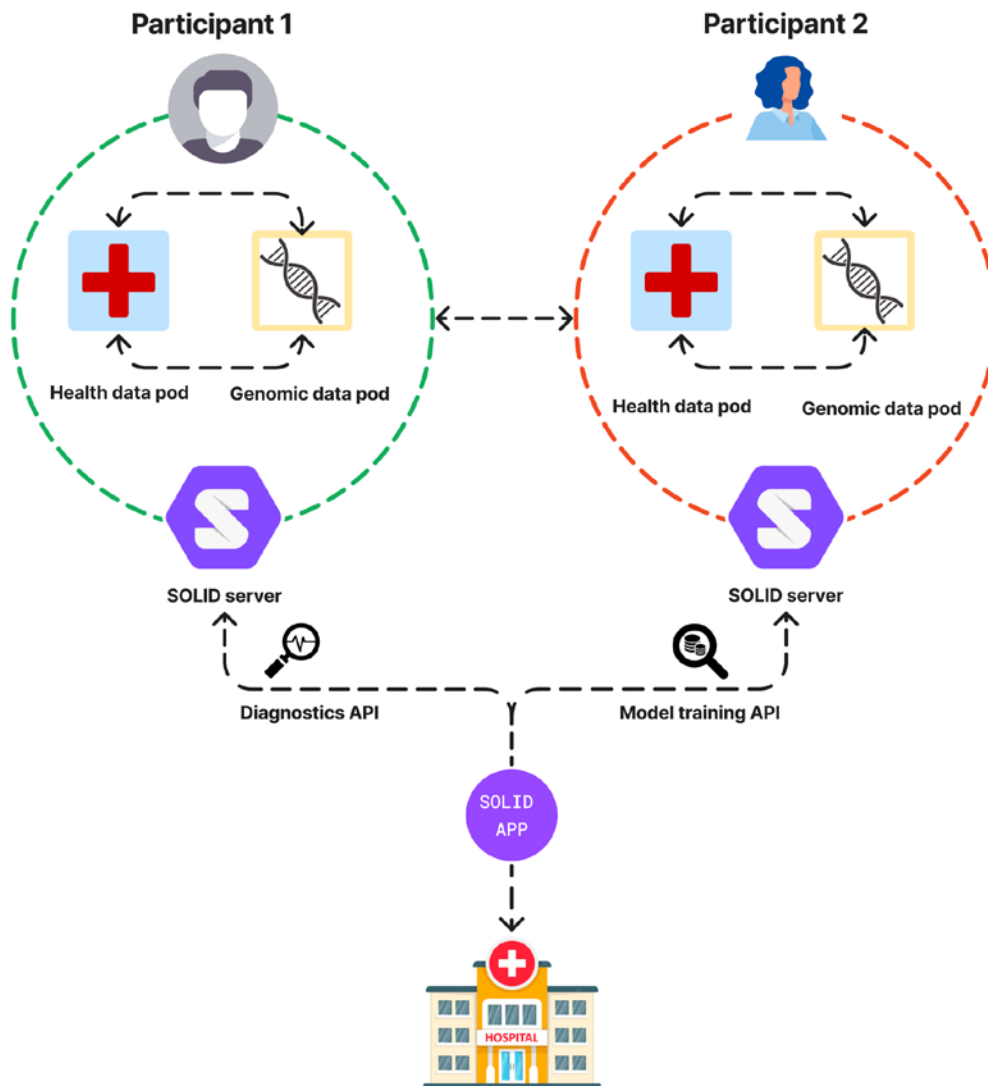
Solid PODS storage space for different users

The preliminary study provided us with valuable insights into a potential future-proof data access mechanism. We are currently monitoring the updates in the solid pods specifications as they evolve, to identify opportunities to incorporate pods within our suite of tools, such as sBeacon and the dynamic consent framework.

Pathling for genomics and feature enhancement of Atomio

Collaborators: eHealth's Health Data Semantics and Interoperability Group.

By facilitating development of software serving genomic and medical ontology terms in accordance with relevant APIs (such as Fast Healthcare Interoperability Resources (FHIR) and Global Alliance for Genomics and Health (GA4GH)'s Beacon Protocol), the prospect of integrating the technologies and expertise between CSIRO groups has the potential to be realised, particularly by future potential of building multiple APIs to allow CSIRO software to achieve a greater degree of interoperability and adoption.

Additional security enhancements and controls have been implemented in CSIRO software Atomio, enabling a greater extent of customer configuration about the handling and serving of sensitive data between multiple user groups. These configuration options meet the same interface as other CSIRO products, providing a consistent interface that incentivises and meets client's needs for greater security and privacy control.

Further feature additions and enhancements of the search potential of medical ontology terms in the context of genomic querying (such as provided by sBeacon and Pathling) enables more accurate and contextually relevant retrieval of genomic and health information and facilitates a more nuanced exploration of genomic data within the broader context of medical knowledge, potentially accelerating discoveries and improving patient care.

Pangenomes and their application

Collaborators: Mayo Clinic, Minnesota, USA

In Somalis, coronary artery disease (CAD) is the 3rd highest cause of death per year (4.57% as per 2020 WHO statistics). However, genetic studies on Somalis and other Eastern African populations remain severely limited. These populations possess unique ancestral genetic components not adequately represented in existing linear references, making it less reliable for genetic research. Collaboration between Dr. Angad Johar, Rachel Foares has resulted in the creation of a pangenome, aiming to develop a more suitable reference for these individuals.

It has been observed that the North African Mozabite population exhibits the lowest proportion of the total genetic variance (Fst value), and the highest ancestral contributions to Somali populations among all source populations outside of East Africa, averaging 22%, which makes this population a promising choice to build the variation-graph for this study. Comparatively, the Bedouin population served as an appropriate control group due to their minimal genetic divergence (Fst value around 0.01) and strong ancestral affinity with the Mozabites.

By using this new variation-graph, which encompasses all known variations of the population in a single reference, the alignment of genetic data from the population of interest becomes more targeted and accurate. This inclusive approach facilitates genetic research on a larger scale, allowing for a more comprehensive understanding of CHD mutations in the Somali population. Consequently, this study will open the door for personalised medicine tailored to their genetic profiles, ultimately enhancing the effectiveness of available treatments.

Host-pathogen interactions

Collaborators: Translational Research Institute (Brisbane), Princess Alexandra Hospital (Brisbane), Rutgers University (USA)

The recent COVID-19 crisis has highlighted the importance of a rapid and effective biothreat response for safeguarding human health. This not only includes rapid flagging of concerning pathogens, but the ability to triage affected patients to ensure they receive the appropriate care. However, our understanding of the pathophysiology of infectious diseases such as COVID-19 and tuberculosis is lacking. As demonstrated by the Host Genetics Initiative, there are specific genes that predict COVID-19 outcomes as well as the risk for long-COVID. We postulate that viral disease susceptibility is likely a complex trait, governed by multiple genes and mutations working together, both within the host and between the host and pathogen.

This project utilises ML algorithms and spatial transcriptomics to develop gene signatures associated with disease severity and identify potential drug targets. We have identified novel SARS-CoV-2 mutations in the NSP14 protein which correlate with more severe disease, and functional validation of these novel loci are currently underway. To paint a more complete picture of host-pathogen interactions modulating disease response, we will apply our pipeline to host genome data to find genomic determinants in the host which correlate with disease severity.

Transformational Bioinformatics: postdoc and student highlights

Postdoctoral fellows

Carol Lee, CERC Postdoctoral Fellow

Analysing host-pathogen interactions and treatment in infectious disease

Leveraging current understanding of diseases and applying machine learning techniques can enable host-pathogen interactions to be deciphered and therapeutic targets to be identified. Disease outcomes can also be modelled and predicted. Differential analyses were performed on tissue infection data to identify significant components by treatment. The results are instrumental in extracting important features that determine disease outcome. The information has furthered understanding of the mechanism of action of different therapeutic treatments including vaccines.

Engineering highlight

Anuradha Wickramarachchi

Data sharing in genomics is challenging, yet an essential task for researchers, clinicians, and big pharmaceutical organisations. Access to high-quality data enables effective diagnosis, faster drug discovery, and secure knowledge exchange into the genomes. Anuradha Wickramarachchi of the Bioinformatics Products team is the lead developer of sBeacon and implemented the Beacon V2 protocol introduced by GA4GH for genomic and phenotypic data exchange. sBeacon was recently accepted for publication in the Nature Biotechnology journal. Thanks to sBeacon's serverless architecture it performs faster yet in an exceptionally affordable manner and it is currently being used by our collaborators at UMCCR in their work. Anuradha's research will make genomic data sharing more accessible, secure, and private.

Masters students

Julika Wenzel, Bioinformatics Student Exchange Program (BSEP)

Identifying synergies in proteomics data to understand cancer pathology

Synergies in proteomics data are non-additive effects found in statistical interactions. Identifying synergies that explain given drug responses can provide insight into cancer treatments. A proteomics dataset containing 949 cancer cell lines from 28 tissues was examined. Random forest models (machine learning algorithms) were used to reduce the dimensionality of interactions to identify potential synergies. Possible synergies were tested via regressions. The tool was the expanded and validated using other methods and available datasets.

The Biomedical Informatics group

Group Leader:
Dr Jurgen Fripp

Our group works at the interface of precision medicine and artificial intelligence, which together have the potential to revolutionise healthcare.

We leverage the ability of artificial intelligence to generate insights into disease prediction, staging, prevention and treatment and empower clinical decisions. Our work in precision medicine focusses on discovery and validation of novel medical imaging biomarkers from MRI, PET, CT, US, and Xray. AI-guided insights integrate -omics, neuropsychology, smart sensing, and clinical phenotypes.

Our informatics platform and the imaging, statistical and AI/ML techniques developed on it enable reproducible and scalable cloud and standalone software deployment. These are applied within in a wide range of large observational and randomised control trials across the human lifespan and disease spectrum, including osteoarthritis, cerebral palsy, cancer and dementia. Our technology is being developed as Software as a Medical Device (SaMD).

We are a key partner in many clinical trials and studies in Australia and internationally. We contribute to the collection and analysis of data across a range of medical conditions including Alzheimer's disease and neurodevelopmental conditions:

- Dementia is the second leading cause of death among Australians and, as our society ages, may become the leading cause of death. The hallmarks of dementia are characterised by a range of fluid and imaging biomarkers, including amyloid and tau PET. As a key partner in the Australia Dementia Network (15 institutions nationwide) and the Australian Imaging Biomarker Study of Aging (AIBL), our group provides advanced image analysis and biostatistical expertise. This is highlighted by contribution to over 20 journal papers in the last 12 months.

- More than 20,000 infants are born premature and/or with low birthweight in Australia each year. These children are at risk of neurodevelopmental conditions, such as cerebral palsy, which can result in a range of adverse cognitive, behavioural, educational, and motor outcomes. We are working with multiple partners including the University of Queensland, Monash Health, and the Cerebral Palsy Alliance to contribute to 11 projects that allow us to track brain development and investigate functional brain networks. These studies, conducted from preterm infancy to adolescence, provide insight into neuroplasticity following insult or intervention. The results can be used to improve clinical reporting and tailor effective therapies to enhance quality of life for the children and their families.
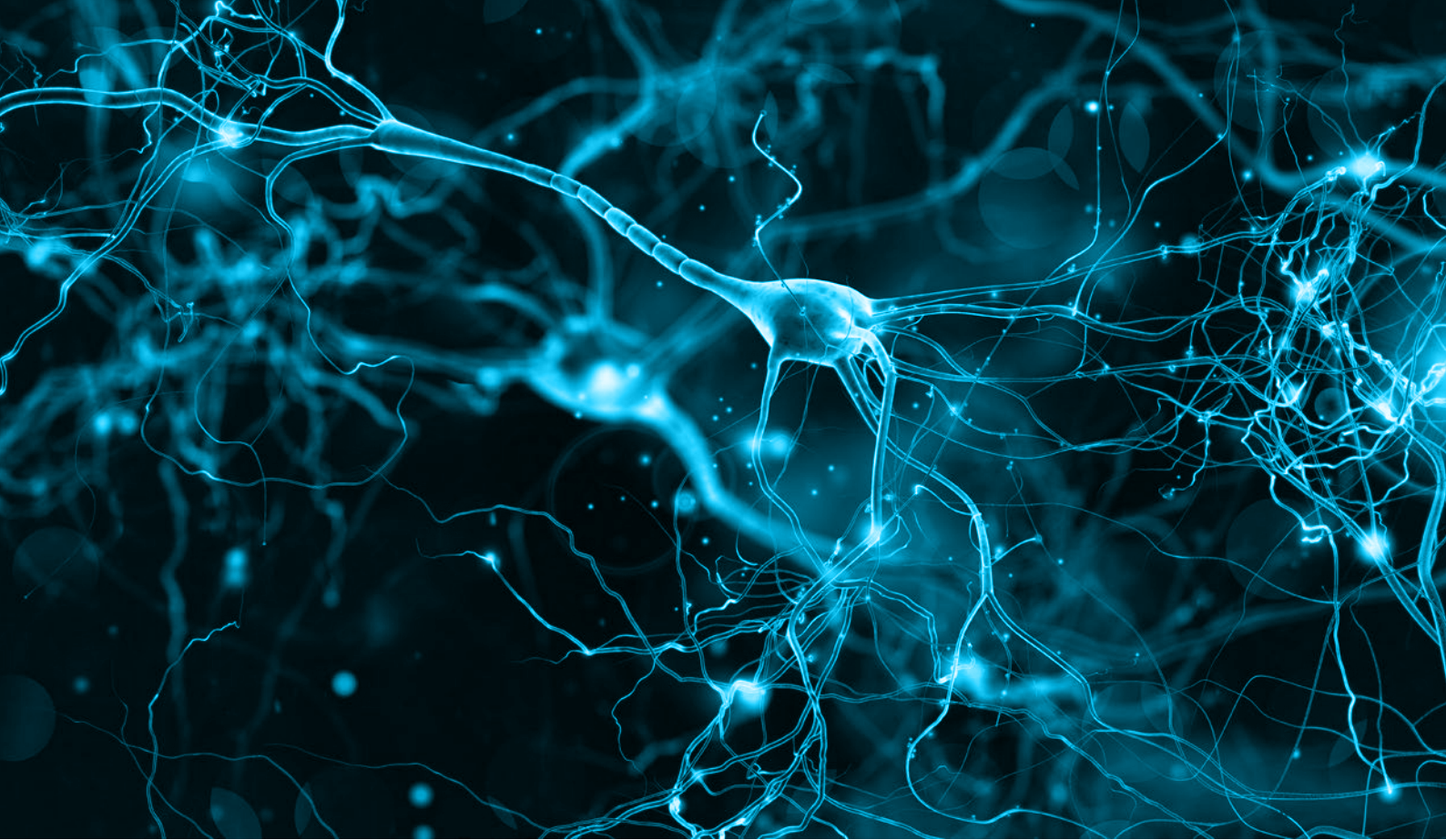
Biomedical Informatics' science and impact highlights for 2022/23

- Further development of a tool to accurately evaluate the morphology and degeneration of cartilage from MR images. In partnership with the University of Queensland, our software has been commercialised by Siemens Healthineers (Chondral Quant).

- A team of our postdoctoral fellows participated in ImageCLEF, an international challenge to build the best AI system for medical imaging tasks. The team won the tuberculosis detection from CT task and came 3rd in the image captioning task.

- We demonstrated the value of early MRI scans in providing measures that could predict two-year outcomes for babies born very premature. Accurate predictions could be made for motor, cognitive, and, to a lesser extent, language scores.

- In children with severe neuropathology, current techniques to segment and measure brain structures are inaccurate. We developed a novel automated approach to segmenting areas of the brain, including the deep grey matter and the corpus callosum, which outperformed three state-of-the-art methods and could be used in future trials to improve predictions of patient outcomes.

- Our cloud platforms and image analysis technology support the collection of data for a range of cohorts and trials. The Australian Dementia Network is using our platform nationwide (six sites in five different states) to calculate MRI and PET imaging biomarkers. Detailed data has already been collected from over 1100 participants.

Medical Image Analysis team

Team Leader: Dr Jason Dowling

The Medical Image Analysis team is developing novel AI technology to enable precision medical imaging (from MRI, PET, CT, US, and Xray). We collaborate closely with clinicians, industry, and patients to understand their needs. The precision imaging AI and machine learning technologies that we develop, validate, and translate can improve disease diagnosis, treatment planning, and treatment delivery. We are currently developing AI and ML methods for the extraction, quantification, and modelling of information from 2D and 3D medical images and sensors; mapping data across imaging modalities and individuals/populations; and performing image reconstruction and synthesis. Clinical applications include radiation oncology, cardiology, respiratory physiology, orthopaedic surgery, and musculoskeletal image analysis.

Neurodevelopment and Plasticity team

Team Leader: Dr Dana Bradford

Our team is developing advanced neuroimaging technology (from MRI) to accurately localise and measure the extent of neuroplasticity for both research and precision medicine applications. The goal of this research is to provide earlier detection and improved diagnosis for childhood neurodevelopmental disorders including cerebral palsy and epilepsy as well as other brain trauma.

Neuroimaging team

Team Leader: Dr Vincent Doré

The neuroimaging team develops neuroimaging technology and machine learning algorithms to extract clinically meaningful metrics from MRI and PET images for use in precision medicine applications. Our research extends across a range of clinical challenges, including developing software as a medical device (SaMD) applications related to Alzheimer's disease. The suite of precision medicine biomarkers developed within the team are used in the discovery and validation of fluid biomarkers. The techniques can be employed in characterising at-risk for developing dementia groups and enable early interventions to be put in place.

Biostatistics team

Team Leader: James Doecke

Our team elucidates the complex relationships between fluid and imaging biomarkers, genes, lifestyle, environment, cognition, and disease pathology. We have specialists in bioinformatics and statistics who apply their knowledge to medical data to identify disease-specific relationships. Our bioinformaticians develop software to process raw genomics data into usable summary information, while our biostatisticians provide reproducible reports for each project to customers. Our collaborators rely on our specialist analytical collaborations to move their research from the bench to the bedside.

Biomedical Informatics: platform technologies

Milx: Medical image processing platform

This medical image analysis platform supports the analysis of a suite of medical imaging modalities (MRI, PET, CT and US) used within our clinical research projects and trials. Milx 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.

The 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 AI and ML 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 viewed 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 $A\beta$ 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 vital 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 $A\beta$ 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 $A\beta$ imaging scans, including in Australia's remote areas.

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

MilxCloud applications: AssessCP

AssessCP is a web-based tool to support the assessment of paediatric brain MRI by providing quantitative information of brain structure (including anatomical volumes and cortical shape) relative to a typically developing cohort as a Z-score, and a visualisation of brain lesions. It utilises a range of AI and ML techniques designed to be robust to potentially severe brain injury, making it able to quantitatively assess children with cerebral palsy (CP) and acquired brain injury (ABI). To support clinical translation, these quantitative measures are then provided in an automatically generated PDF report to clinicians, to illustrate where the patient sits relative to an age-matched typically developing cohort.

This software has been used in a number of projects to find cross-section associations between brain structure and childhood function in collaboration with Queensland Cerebral Palsy and Rehabilitation Research Centre (QCPRRC), elucidate subtle differences in brain structure associated with genetic markers associated with CP (with collaborators in Monash University, Phoenix Children's Hospital), and is currently being used to process existing clinical data from multiple European sites as part of the AInCP Horizons grant (Fondazione Stella Maris, University of Pisa). It is being validated on a large paediatric cohort (combined n=366) of children born preterm or with CP, after which a trial version will be available on MilxCloud.

Health research data: CSIRO AWS REDCap

The collection of data (personal and medical) is one of the most important steps in any clinical study or trial concerning human health. We 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, a web application used to manage and capture basic clinical research data; 2) XNAT, an imaging informatics platform used to capture imaging data, and 3) Dashboard, an in-house web application that allows for a seamless experience in dealing with data entry, collecting summary data, and completing study specific tasks.

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

FORTE – Workflows in FHIR

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

Fast Healthcare Interoperability Resources (FHIR) is a standard for storing and querying health care data which is being rapidly adopted into the clinic. The concept of workflows is modelled in FHIR. This allows 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 AI systems) and decision support systems directly into the clinical workflow. Based on this platform, we have now developed a prototype RIS that allows us to showcase our tools and workflows including several AI tools that have been developed in the lab. We are also collaborating with the Royal Australian and New Zealand College of Radiologists (RANZCR) in further developing our platform and exploring alternate clinical workflows.

SKULLPRO2: Remote monitoring for Craniectomy patients

People who have suffered from stroke or traumatic head injury can experience potentially fatal brain swelling requiring surgery to remove a section of skull (craniectomy) followed by reconstructive surgery (cranioplasty) at a later date. During this interval, patients need to cover and protect the skull defect in some way. Typically, this is done with unsuitable sports helmets. As an alternative, CSIRO Manufacturing and Anatomics developed a slim, patient matched and contoured tough nylon shell that provides aesthetic cover for skull deformities. The thin shell sits inside a hypoallergenic, washable fabric pocket held in place with a breathable mesh band or beanie.

In 2021, Data61 embedded sensors into the SkullPro device for remote monitoring in the patient's environment. In 2022–2023, AEHRC contributed to this platform development through user needs analysis and co-design of a web app for clinicians to visualise the data in real time. A proposed patient-facing app will complete the platform for use by neurosurgeons and rehabilitation specialists.

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 internal and external use given project requirements. Collaborators and team members design statistical analyses plans (SAPs) to investigate data as per collaborator research priorities. Once the SAPs have been agreed upon, team members design, produce and deliver reproducible reports using ML and AI methods to 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.

A focus within the team is to develop and use novel methodologies to assess longitudinal trajectories of Alzheimer's disease biomarker data. Team members work with researchers and scientists within the Australian Imaging, Biomarkers and Lifestyle (AIBL) study of ageing on many projects involved in the development and investigation of benchmark blood-based biomarkers to detect Alzheimer's disease pathology.

Shown below is an example of a R Shiny app to visualise data from the AIBL. The app is being developed with multiple functions to both guide clinical decisions and direct research designs.
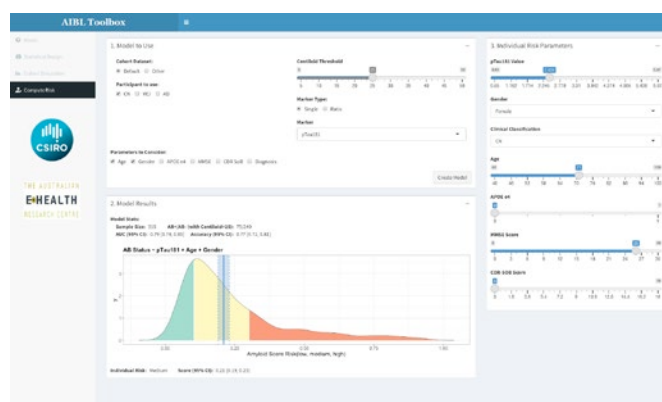
Data visualisation through R Shiny.

Biomedical Informatics: project reports

Australian Dementia Network (ADNeT)

Australian Dementia Network
REGISTRY. CLINICS. TRIALS.

Collaborators: University of Melbourne, University of New South Wales, Monash University, Edith Cowan University, Flinders University, South Australia Health and Medical Research Institute (SAHMRI), University of Sydney, Neuroscience Research Australia, Macquarie University, QIMR Berghofer, University of Tasmania

ADNeT is a five-year NHMRC-funded collaboration with 15 partners across Australia. Its primary aim is to improve the quality of care, the diagnostic accuracy, and accelerate the development of new therapies. One major outcome has been the establishment of an integrated network of dementia researchers, clinicians, and health service providers. The network is enabling ongoing, high-quality translation of research into clinical care for Australians living with cognitive impairment and dementia. In addition,

ADNeT enables fast recruitment of trial-ready research participants and supports participants through their involvement in clinical trials. Over 3300 subjects have volunteered for recruitment into trials, with 1100 subjects enrolled into the well characterised trial-ready cohort.

CSIRO is joint technology lead, providing the following:

- Technology support: Providing secure data collection platform and harmonisation for the ADNeT consortium.
- Image analysis: Providing imaging biomarker quantification and clinical translation for the thousands of medical images associated with this project. This currently includes MRI analysis and amyloid and tau PET analysis.
- Statistical analysis: Our Biostatistics team combines data from multiple modalities to answer clinical research questions. This involves using statistical methods to combine data from imaging, genetics, genomics, proteomics, neuropsychology, and clinical biomarkers. They are investigating the destructive pathological processes that occur to cause Alzheimer's disease.

CSIRO is collaborating with 15 partners across Australia to further Alzheimer's research.

Prediction of childhood Brain Outcomes in infants born preterm (PREBO-6)

Collaborators: Queensland Cerebral Palsy and Rehabilitation Research Centre, University of Queensland, Herston Imaging Research Facility
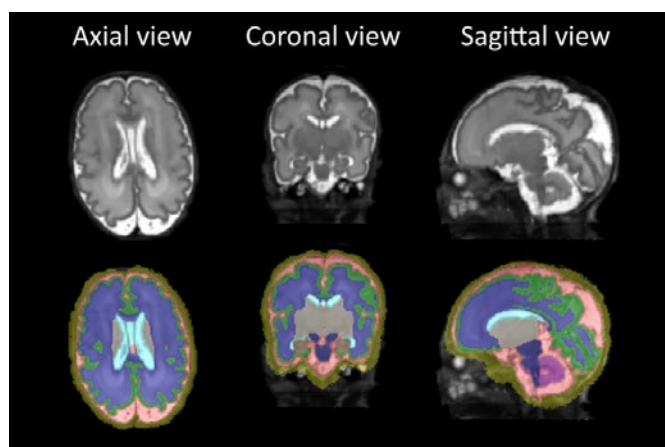
In the last decade, about 150 million children were born pre-term. Pre-term infants face a range of adverse neurodevelopmental outcomes, including cognitive, behavioural, educational, and motor deficits. In collaboration with the Queensland Cerebral Palsy Rehabilitation and Research Centre, we followed up our landmark preterm cohort (PREBO) at six years to determine if MRI scans of preterm infants acquired at 29-35 weeks postmenstrual age are predictive of academic achievement and health outcomes at 6-years.

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

Early neonatal brain MRI measures predict motor and cognitive outcomes at 2 years corrected age in very preterm infants

Our research is investigating the predictive value of early (before term equivalent age) MR imaging in predicting developmental outcomes at 2 years.

The study utilises a cohort of 181 infants born <31 weeks' gestation, who had 3T MRIs acquired at 29-35 weeks postmenstrual age. The infants had a comprehensive neurodevelopmental evaluation at 2 years corrected age. We applied advanced structural MRI pre-processing steps to standardise the data and leveraged the state-of-the-art developing human connectome pipeline (see figure) to find important brain biomarkers from the early MRIs. We identified multiple biomarkers that were predictive of 2-year outcomes, including cortical grey matter volumes, as well as cortical thickness and sulcal depth across the entire cortex.
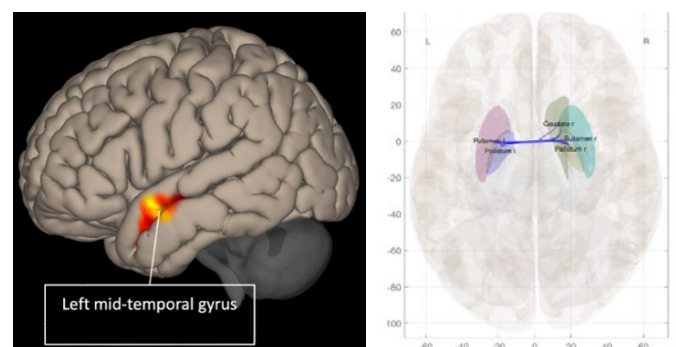
This research demonstrates the utility of early neonatal MRI imaging prior to term equivalent age for providing earlier commencement of targeted interventions for infants born preterm.

Using functional brain scans to predict brain development in 6-year-old children born pre-term

We are using fMRI brain scans to explore how the brain responds during motor activities and how different parts of the brain communicate with each other at rest.

The brain activity of children born very preterm is different to those born at term. Particularly, when children born preterm use their right dominant hand, a brain area on the left side, called the mid-temporal gyrus, is more active. This suggests that these children might use different parts of their brains or think differently to perform movements, possibly because their brains are making up for some difficulties. When we looked at how different areas of the brain interact with each other while the kids are resting, we found important differences in patterns. In preterm children, the communication within deep areas in the brain was weaker than expected. This could be why some preterm children might have difficulties with movement.

Our findings suggest being born very preterm can have long-lasting effects on how the brain develops. This could be because the brain is adapting in higher-level ways, making up for certain difficulties, or just developing differently. Understanding these brain changes helps us to identify which kids might need extra help. It can also lead to better ways to support children born preterm in overcoming the challenges they may face as they grow. This project is opening doors to knowing more about brain development in children born preterm and is paving the way for creating stronger support systems and tools for these children.

Example segmentation of the neonatal brain MRI using the developing Human Connectome Project pipeline.

(Left) Children born preterm show different brain activity during hand movements. The picture shows the left side of the brain being extra active during right-hand tapping in an area we would not expect to see light up during hand tapping. (Right) Preterm children have weaker interactions (blue line) between deep brain structures at rest.

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

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

AI system is being developed to identify patients with complex distal radius fractures (DRFs) that may require further CT scan and examination. We have established a two-stage deep learning DRF classification pipeline which imitates clinicians' search patterns. The framework zooms in on the distal radius region of interest using an ensemble model based on YOLOv5 object detection network and classifies the DRF in the region as an intra- or extra-articular fracture using an ensemble model based on EfficientNet. The identification of intra-articular fracture can alert clinicians of fractures extending to the joint surface which could have long term functional impacts on the joints and may require CT scans.

In the past 12 months, we have completed the development of the single-view AI framework for intra- and extra-articular DRF classification. A journal paper titled 'Automatic classification of distal radius fracture using a two-stage ensemble deep learning framework' was published in *Physical and Engineering Sciences in Medicine*. We have also extended the framework into a dual-view system incorporating both PA and lateral views, which further improved the discriminative ability for DRF classification. An abstract titled 'Distal radius fracture classification on dual-view radiography using ensemble deep learning framework' has been presented at *the Computer Assisted Radiology and Surgery 2023 Conference* in Munich, Germany.
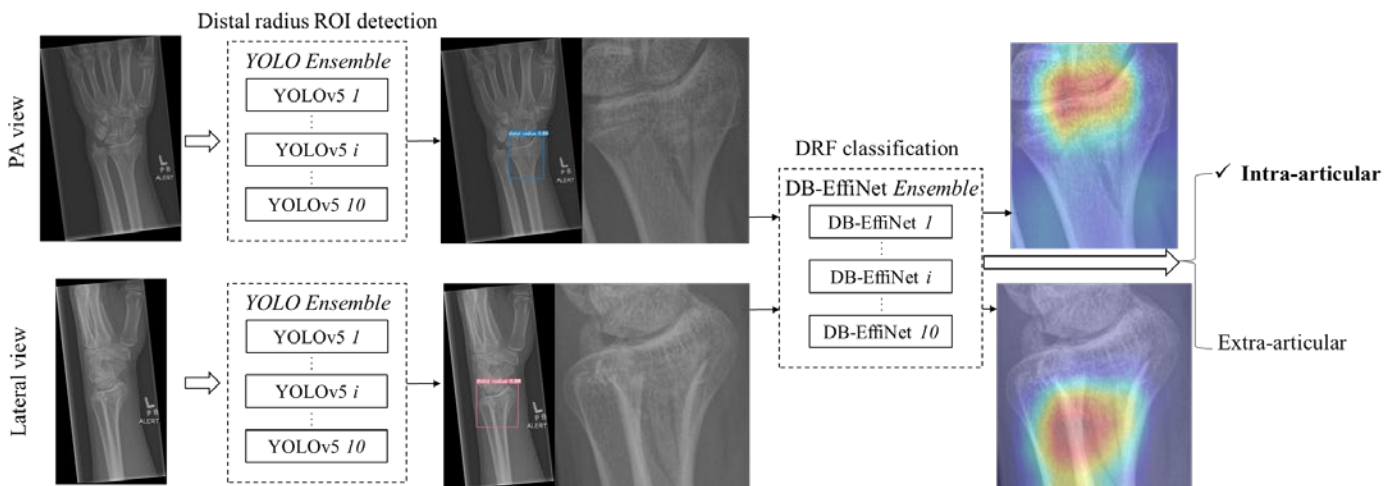

Diagram of DRF classification using YOLO ensemble network and dual-branch EfficientNet (DB-EffiNet) ensemble.

Improving radiotherapy treatment clinical trial quality assurance

Collaborators: Ingham Institute, Liverpool Hospital

We are developing novel AI methods for 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 potential to improve recommendations from clinical trials, identify contouring inconsistencies in real time, and normalise retrospective trial results.

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

Clinical target volume and organs of risk quality assurance AI framework and its deployment into the NINJA trial

We have developed a new automatic delineation QA system on prostate MRI for both the clinical target volume (CTV) and organs-at-risk (OARs). This QA system uses a deep learning segmentation network to provide the benchmark delineations and area of uncertainty. An ML classifier then suggests 'pass' or 'requiring further review and revision' for manual delineations based on their spatial association to the deep learning network's outputs. A PDF QA report is generated for the clinicians, which shows the QA outcome and visualises the differences between the manual and computer-generated delineations.

This QA system was evaluated on the MRI-only studies in the NINJA radiotherapy trial with promising results. The QA system for prostate CTV delineation was deployed with TROG in the ongoing NINJA trial and has undergone the first phase of clinical validation. A manuscript with details of the method was published in *Radiotherapy and Oncology* (IF 6.9). In the next stage, the CTV QA system will be upgraded based on the first phase validation outcome and the OAR QA system will be deployed.
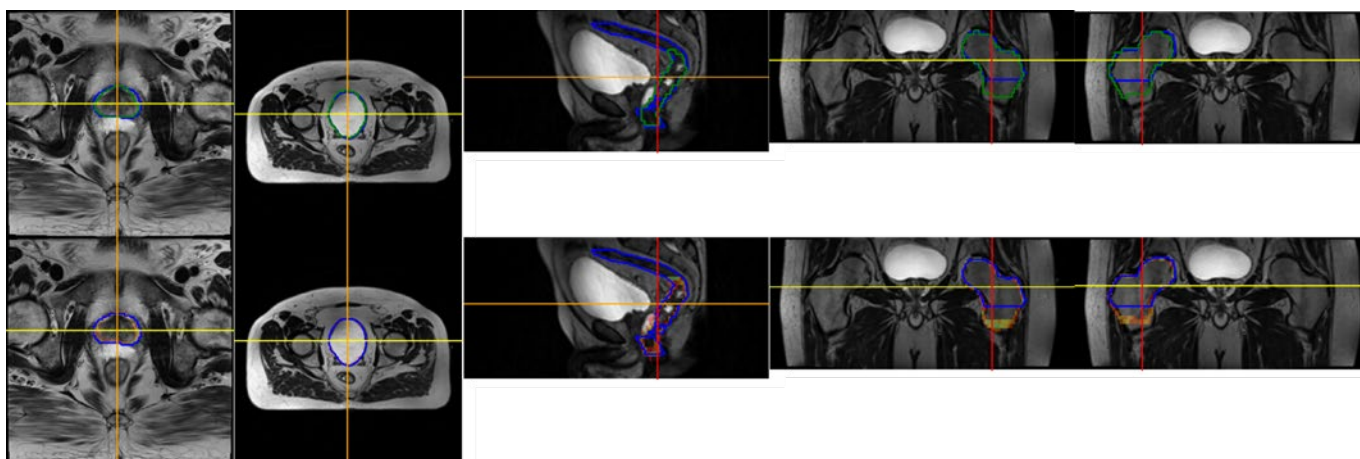
Automated QA examples of the prostate (requires further review), bladder (pass), rectum (requires further review), left femur head (requires further review) and right femur head (requires further review). The blue outline is the manual delineation, and the green outline is the DL network generated delineation. The heatmap in the second row represents the area of uncertainty by the DL network.

Biomedical Informatics: project updates

NINJA multi-centre clinical trial

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

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

Participants are randomly assigned to one of two radiotherapy schedules as part of this study. In schedule 1 (called Stereotactic Body Radiotherapy) participants receive 5 radiotherapy treatments over 2 weeks, and in schedule 2, (called Virtual High Dose Rate Boost), participants receive stereotactic body radiotherapy delivered in 2 treatments over 1 week followed by 12 treatments of conventional external beam radiotherapy over 2 and a half weeks.

This research has potential to improve the accuracy and quality of radiotherapy treatment in prostate cancer. An important component of the study includes validation of MRI-only radiation therapy treatment at eligible sites. This involves the generation of synthetic CT from patient MRI scans to enable dose delivery planning using CSIRO's sCTGen software. To date 62 men in this trial have been treated with sCTGen (TGA: CT-2020-CTN-03318-1; ACTRN12618001806257; Protocol: https://bmjopen.bmj.com/content/9/8/e030731).

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 used in the NHMRC grant project 'MR Hip Intervention and Planning System' (mrHIPS), which enables bone lesion and soft tissue visualisation and quantification, and a framework for modelling of hip joint kinematics. These models have been enhanced through image acquisition using the 7T MRI scanner at the University of Queensland. Both projects are supported by Siemens Healthineers, Germany, who are the commercialisation partner for the technology. This software is evaluated and additional data collected by several international collaborative imaging sites to support regulatory approvals.
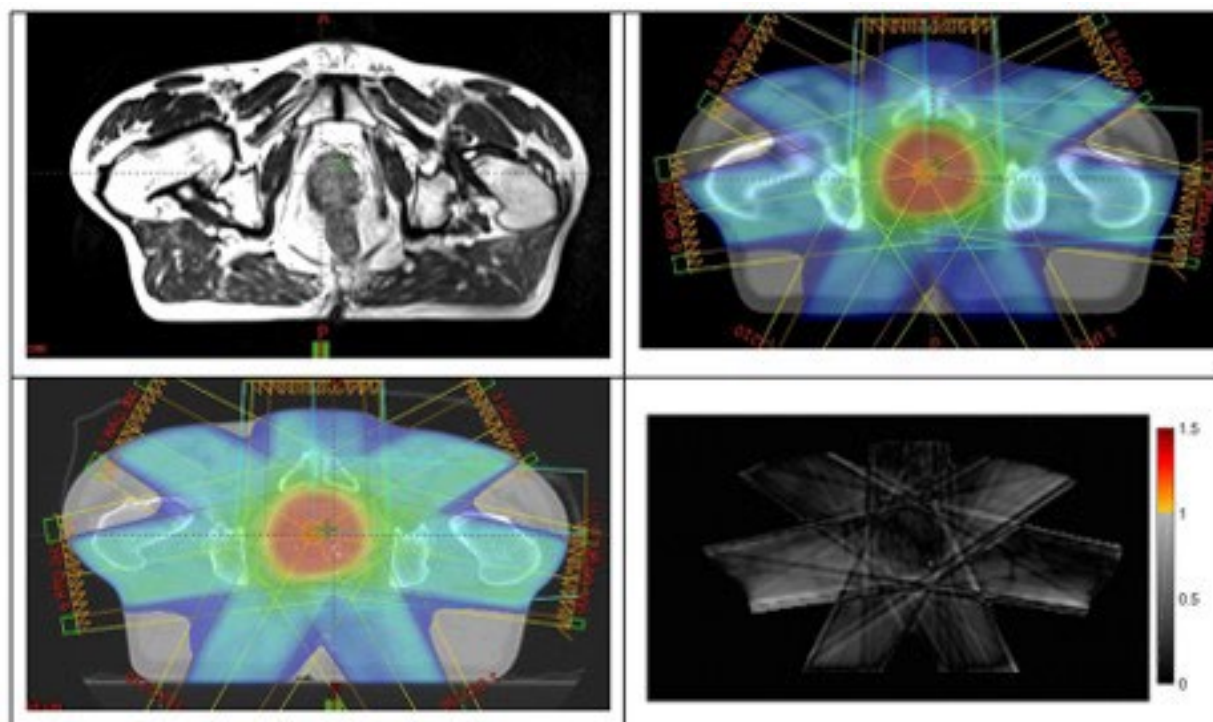
An axial slice from a patient's MRI scan (top left) and matching MRI generated synthetic CT with dose plan (top right). A comparison CT is shown bottom left and dosimetry quality assurance (bottom right).

MRI-based paediatric lung structure and function assessment

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

This project will improve health outcomes for children with cystic fibrosis and ataxia-telangiectasia (A-T) by using MRI to provide information on lung status. Currently the most informative method for lung imaging in these children computed tomography (CT) scanning which increases a child's cancer risk due to the radiation dose delivered. To address this, we are developing acquisition methods and software to extract quantitative information from MRI. This work is supported external funding from the AT Children's Project, the US CF Foundation, and a 2020 NHMRC MRFF grant.

Progress over the past 12 months:

- Developed a synthetic lung CT algorithm to address the pairwise spatial misalignment issue. The paper has been submitted to the premier computer vision conference NeurIPS 2023.

- Developed a lung segmentation algorithm on UTE-MRI based on domain adaptation and presented poster to European Congress of Radiology 2023.

- Paper on 'Ultrashort Echo-time MRI and Fourier Decomposition MRI for Structural and Functional Pulmonary Abnormalities in Ataxia Telangiectasis' under review at journal *Magnetic Resonance Imaging*.

- Accomplished the AT trial phase 2, acquiring follow-up pulmonary MRI imaging from 11 AT patients. We are analysing the MRI results and preparing for journal submission.

- Awarded an R+ PhD scholarship grant ($35,000).
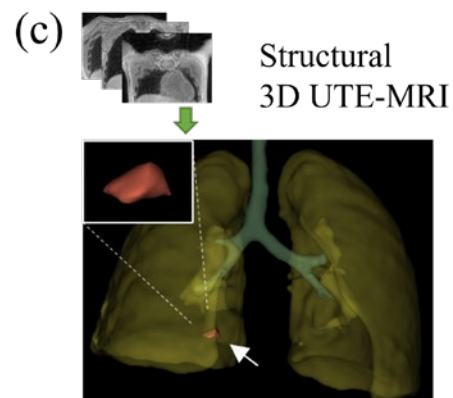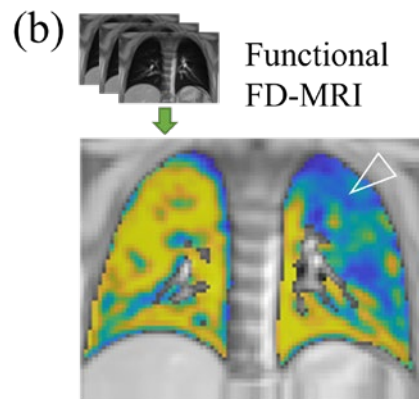
(a) Siemens Skyra 3T MRI (HIRF, RBWH). (b-c) Free-breathing non-contrast-enhanced MRI for detecting abnormalities in children with ataxia telangiectasia. (b) Ventilation defects (in blue) using functional Fourier decomposition (FD) MRI. (c) Consolidation (in red) using 3D structural ultrashort echo time (UTE) MRI.

AI for cardiac substructure screening

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

The coronary calcium score is an electrocardiogram (ECG)-gated CT scan of the lower chest that measures the amount of calcified plaque in the coronary arteries, an imaging biomarker that correlates powerfully cardiovascular risk. However, it requires more advanced CT equipment and preparation than standard chest CT, which vastly outnumber calcium score scans in Australia. Standard chest CT scans are routinely used for the assessment of infection, COVID-19, and cancer surveillance or detection. While coronary calcium indicates risk related to coronary plaque, other cardiac features such as cardiac chamber volumes are more closely related to the risks of arrhythmia, heart failure and stroke. While cardiac CT measurements using ECG-gated CT with contrast injection have been shown to correlate closely to MRI for the measurement of chamber volumes, methods to identify cardiac substructures in standard chest CT remain sub-optimal, due to limited visual cues of the underlying cardiac substructures.

Over the past 12 months, a domain adaptive and adversarial learning algorithm was developed to address the challenges of cardiovascular assessment in standard chest CT. By bridging the domain gap between contrast-enhanced CT and standard chest CT, the novel approach learns to capture essential patterns and latent features common to both modalities, enabling more accurate prediction of cardiac substructures and volumes from standard chest CT. Preliminary experimental results using a cohort of 350 patients, acquired from St. Vincent's Hospital (Sydney, NSW), highlights the potential of this novel approach. In the next stage, validation of the model will be performed against the Multi-Ethnic Study of Atherosclerosis (MESA) dataset, a population-based cohort study of subclinical cardiovascular disease.

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 is well described, but the in vivo distribution, especially the development during early disease stages, is not well understood. This year we disseminated our findings on the distribution of malaria parasite in the brain as measured with FDG-PET, a biomarker for metabolism. This compliments previous work on the distribution in the liver. Together, these publications have demonstrated FDG-PET as a biomarker for malaria and have demonstrated important differences in parasite distribution between different malaria parasites can occur much earlier than previously expected.
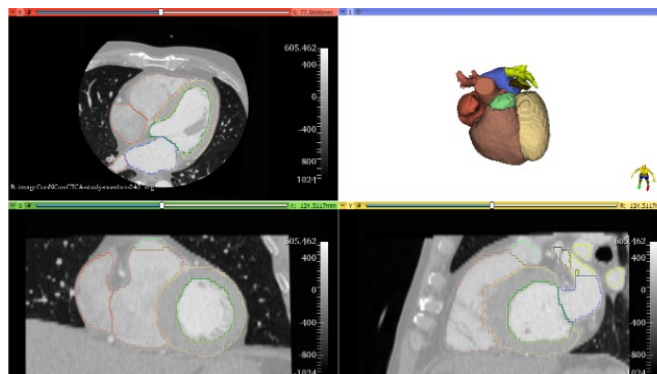
Predicted cardiac substructures in contrast enhanced cardiac CT with proposed algorithm
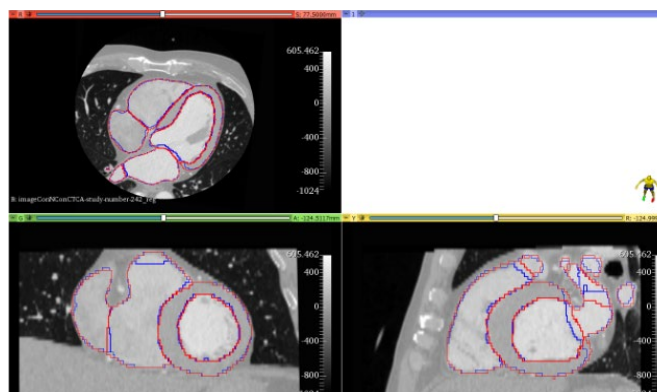
Comparison of predicted cardiac substructures (blue) compared with ground truth substructures (red)
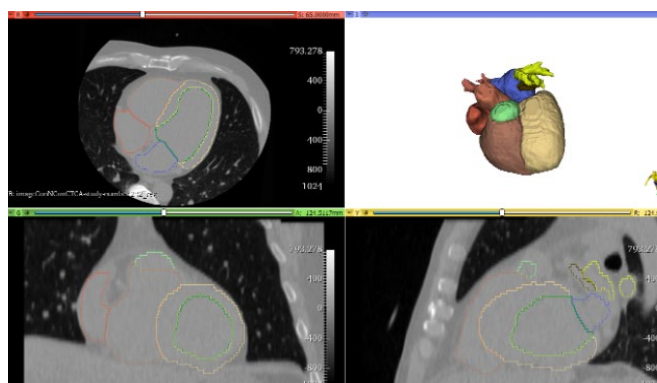
Predicted cardiac substructures from patient's corresponding standard chest CT using proposed algorithm
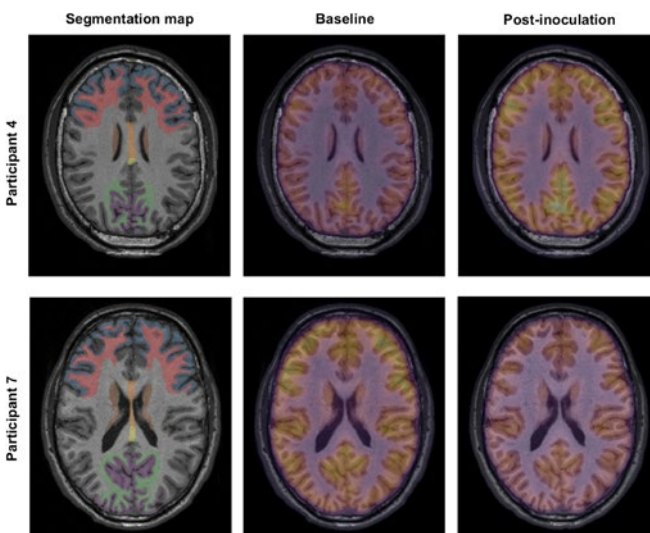
FDG-PET scans of the brain. Changes in FDG uptake following inoculation may provide information on parasite or host activity.

Multimodal learning for medical image analysis

Collaborators: Machine Learning and Artificial Intelligence Future Science Platform (CSIRO) and Data 61 (CSIRO)

We are developing ML and AI methods that consider multiple modalities for application in medical image analysis. Our aim is to reduce the burden of radiology reporting by leveraging multimodal learning to automate image interpretation and radiology report generation. We have been investigating chest X-ray report generation, medical image captioning, and text-to-chest X-ray synthesis. We proposed several improvements to chest X-ray report generation in an article that currently requires revisions for *Artificial Intelligence in Medicine*. We have also achieved success in the international ImageCLEF Medical Image Captioning challenge in which we placed first in 2023.
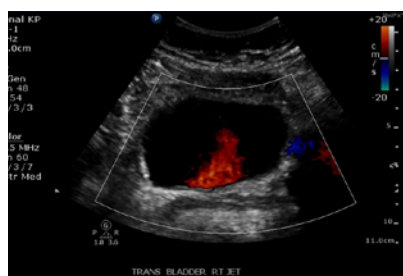
"This image is a transverse evaluation of the bladder and right ureteral jet. Renal ultrasound studies also include evaluation of the ureterovesical junction through Color Flow Doppler study of fluid movement of the ureteral jet."

Medical image   Caption

Results of the medical image captioning task (2023).

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

Collaborators: Anatomics, Data61 (CSIRO)

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

Our objective is to allow clinicians to remotely monitor patients to facilitate optimal pre-operative review, which may lead to improved health outcomes. Working with our collaborators we developed a 'smart' device fitted into a skullcap to measure physiological parameters and relay this information to clinicians via a cloud-based data processing framework (see Platform Technologies). We co-designed a clinician portal with neurosurgeons and tested our device on a recent craniectomy patient. Initial feedback suggests that remote monitoring would be particularly useful for triaging at-home symptoms if paired with our proposed patient facing app.
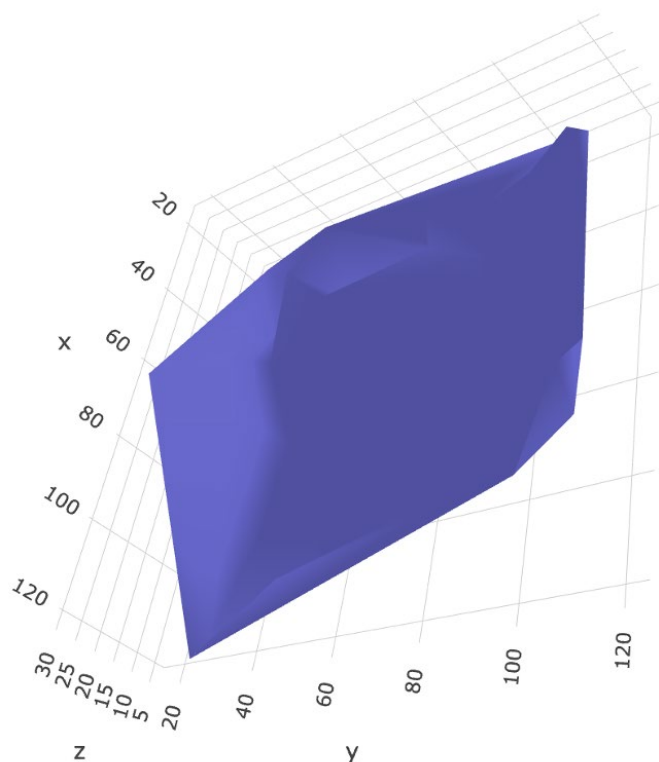
3D visualisation of brain swelling in a patient ready for cranioplasty as presented in the clinicians' portal.

AInCP: Clinical validation of artificial intelligence for providing a personalized motor clinical profile assessment and rehabilitation of upper limb in children with unilateral cerebral palsy

Collaborators: Università di Pisa, Fondazione Stella Maris, Queensland Cerebral Palsy and Rehabilitation Research Centre

We are developing, testing, and validating cost-effective AI strategies to provide evidence-based clinical decision support tools for the personalised and theranostic functional diagnosis, upper limb assessment and home-based intervention in children with unilateral cerebral palsy (UCP). This study, performed in collaboration with sites in Italy, Belgium, Spain, and Georgia, is a unique opportunity to explore a potential intervention for children with UCP. A custom setup quantifies the children's daily movement, analyses its parameters, and provides daily feedback to caregivers through the smartphone.

Cutting-edge data harmonisation approaches will be applied to manage the multi-site imaging data. Existing clinical scans will be analysed using the AssessCP pipeline (see Platform Technologies) to provide a complete functional profile for participants, in conjunction with their physical assessments and sensorimotor recordings. We will then use advanced diffusion and functional imaging analysis to probe potential neurological changes induced by the AInCP intervention. We are in discussion with sites about a standardised protocol and consistent data sharing procedures.

Universal tau sampling mask

Collaborator: Austin Hospital

Tau protein is a structural component of nerve cells that, when abnormally aggregated, is associated with neurodegenerative diseases like Alzheimer's. Recently, an increasing number of tau tracers have become available. There is a need to standardise quantitative tau measures across tracers, supporting a universal scale.

We developed several cortical tau masks and applied them to generate a tau imaging universal scale. 1045 participants underwent tau scans with either ^{18}F-Flortaucipir, ^{18}F-MK6240, ^{18}F-PI2620, ^{18}F-PM-PBB3, ^{18}F-GTP1 or ^{18}F-RO948. The universal mask was generated from cognitively unimpaired Aß- subjects and AD patients with Aß+. Four additional regional cortical masks were defined within the constraints of the universal mask. A universal scale, the CenTauRz, was constructed. None of the regions known to display off-target signals were included in the masks. The CenTauRz allows robust discrimination between low and high levels of tau deposits. We constructed several tau-specific cortical masks for the AD continuum and a universal standard scale designed to capture the location and degree of abnormality that can be applied across tracers and across centres.

The CenTauR masks are freely available at https://www.gaain.org/centaur-project.

- Mesial temporal
- Meta temporal
- Temporo parietal
- Frontal
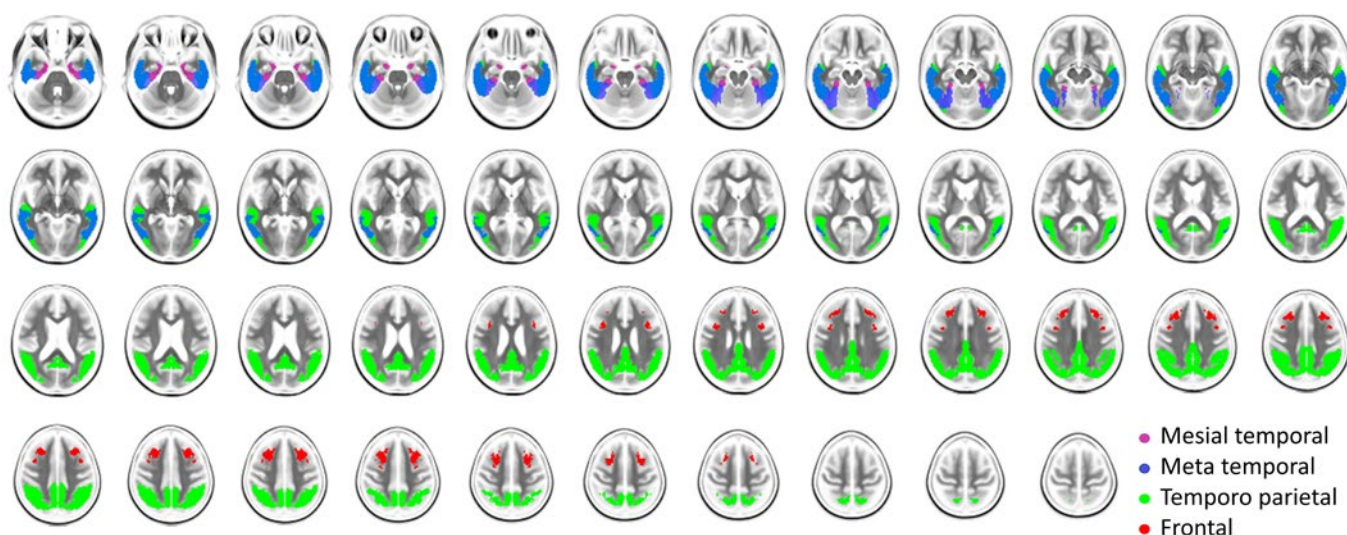
CenTauR sub-cortical masks overlaid on an MRI template.

Harmonisation of amyloid PET imaging across scanner hardware

Collaborator: Machine Learning and Artificial Intelligence Future Science Platform, Austin Hospital, AIBL, ADNet

Accumulation of beta amyloid in the brain is a hallmark of Alzheimer's disease. Positron emission tomography (PET) enables the precise quantification of levels of this protein in the brain. In clinical trials, different types of PET scanners are often used. However, we recently demonstrated that images acquired on different types of PET scanners lead to different measurements. This is due to improvements in newer scanners as well as nuances in how different manufacturers process imaging data. In this new project funded via the Machine Learning and Artificial Intelligence Future Science Platform, we are applying deep learning techniques to learn to minimise differences between different scanners.
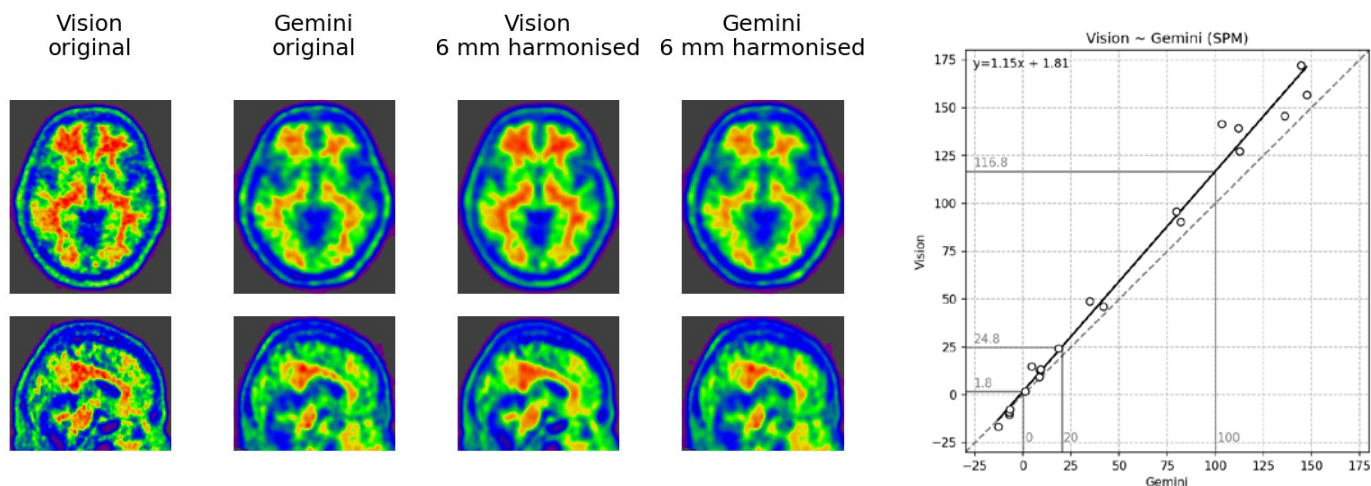
A comparison of beta amyloid PET images with the NAV tracer acquired on the Siemens Vision and Philips Gemini scanners. Left: Differences in the original scans. Middle: Remaining differences even after resolutions are matched. Right: Head-to-head differences in 'Centiloid', the unit of beta amyloid burden.

Quantifiable brain atrophy synthesis for benchmarking of cortical thickness estimation methods

Collaborators: Queensland University of Technology (QUT)

Adequate evaluation of cortical thickness estimation methods requires a longitudinal dataset with quantifiable atrophy (ground truth) between subjects' time points, which is rarely available in medical imaging. This study investigates a method to address this lack of ground truth labelling for cortical thickness estimation evaluation and methods benchmarking. We developed a method that performs brain atrophy synthesis based on existing cortical surface meshes. This was used to create a synthetic longitudinal brain MRI dataset with each subject having 19 follow-up scans (19 levels of atrophy). Using this dataset, we compared the ability of different software to detect small changes in cortical thickness. This allowed us to identify the most sensitive method.
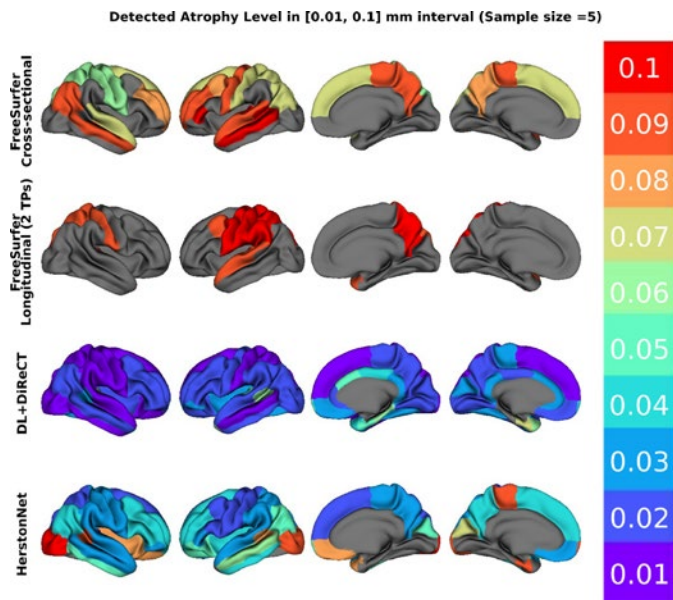
Minimum amount of atrophy that can be detected by different software using our benchmark synthetic dataset. Colour bar represents the smallest detectable atrophy in mm.

Machine learning based composite cognitive test scores: ADOPIC study

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

In clinical trials targeting Alzheimer's disease, cognition is a primary outcome. As the clinical trial transitions into the pre-clinical stage, there is a need for cognitive assessments that capture early progression of the disease. In this project, we compared the longitudinal trajectories of the preclinical Alzheimer cognitive composite (PACC) with those of composite scores optimised through ML algorithms including the uniform manifold learning dimension reduction technique (UMAP), principal component analysis (PCA) and latent variable analysis (LVA). Our investigation, conducted on a comprehensive dataset called ADOPIC, aimed to evaluate the sensitivity and specificity of these composite scores in detecting changes in clinical diagnostics over a period of five years.

In participants at the prodromal stage of AD, PCA and UMAP composites exhibited significantly higher signal-to-noise ratios (SNRs) compared with PACC. However, there were no significant differences in SNRs between the composites for other stages. In conclusion, our findings suggest ML based composite scores have the potential to enhance the accuracy of cognitive endpoints in early AD clinical trials.

Longitudinal cholinergic degeneration in aging and Alzheimer's disease

Collaborators: AIBL Study of Ageing, Australian Dementia Network, University of Queensland

Dysfunction of the cholinergic basal forebrain (BF) system begins during the preclinical stage of AD and persists throughout the disease's progression. This dysfunction interacts with other biological changes in AD, substantially contributing to cognitive impairment. This study characterises the degeneration of the cholinergic BF system in aging and early AD and determines its interactions with other AD biomarkers that contribute to neurodegeneration and cognitive decline. The figure below demonstrates the progressive volume loss in the BF during both the preclinical (with a Clinical Dementia Rating, or CDR, of 0) and symptomatic (CDR between 0.5 and 1) stages of AD.
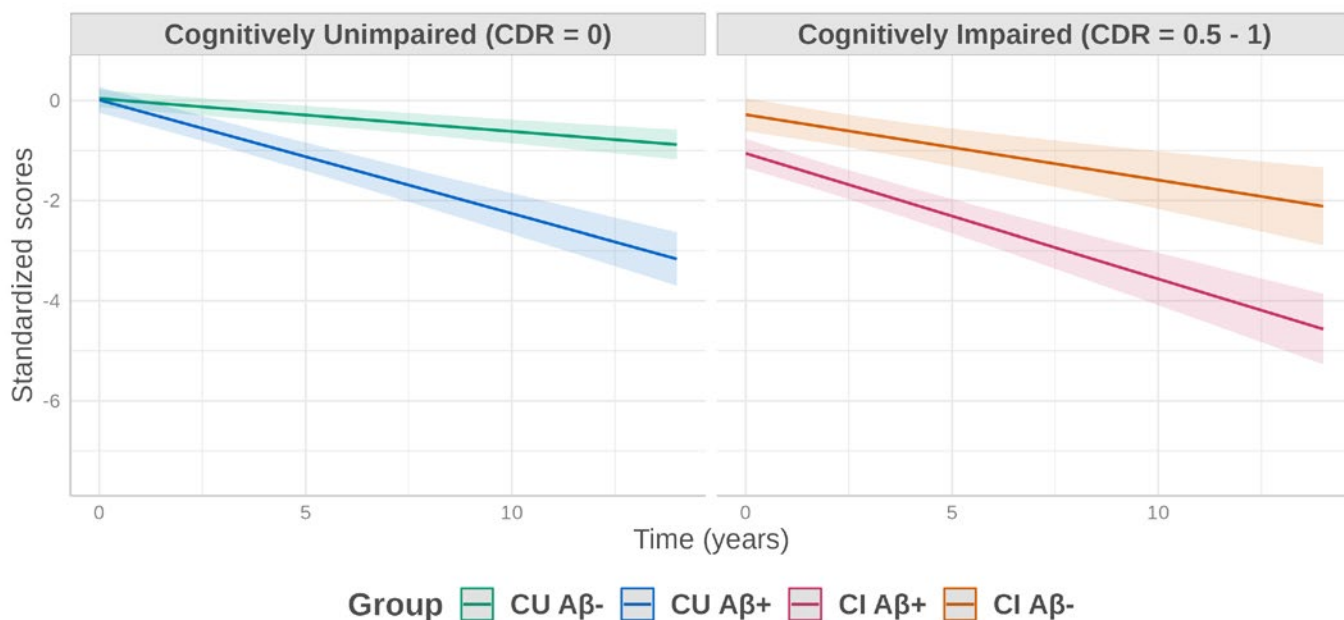
Longitudinal trajectories of basal forebrain volumes (in standardised scores) by group. CU is cognitively unimpaired, CI is cognitively impaired. Aβ+ indicates the presence of abnormal amyloid-β load.

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

Collaborator: AIBL Study of Ageing, Janssen

Over the last 15 years, the Australian Imaging, Biomarkers and Lifestyle (AIBL) study has collected PET imaging data from tracers designed to identify both amyloid beta and tau. By retrospectively analysing blood samples collected simultaneously, using an assay developed by Janssen, we measured the abundance of phospho-tau 217+ (pTau217+). This analysis demonstrated that plasma p217+tau offered high accuracy in detecting Aβ+ individuals across the clinical spectrum. Our data suggest that plasma p217+tau (1) begins to rise soon after brain Aβ levels begin to trend upwards as assessed by PET; (2) concordant with the rise in tau in the amygdala region on PET; and (3) prior to the rise in meta temporal tau PET. In conclusion, an elevated level of plasma p217+tau is associated with both elevated Aβ and tau across the clinical spectrum of AD. Elevated p217+tau strongly supports a diagnosis of AD in persons with mild cognitive impairment or dementia, whereas a low level in cognitively unimpaired participants is strong evidence against preclinical AD.
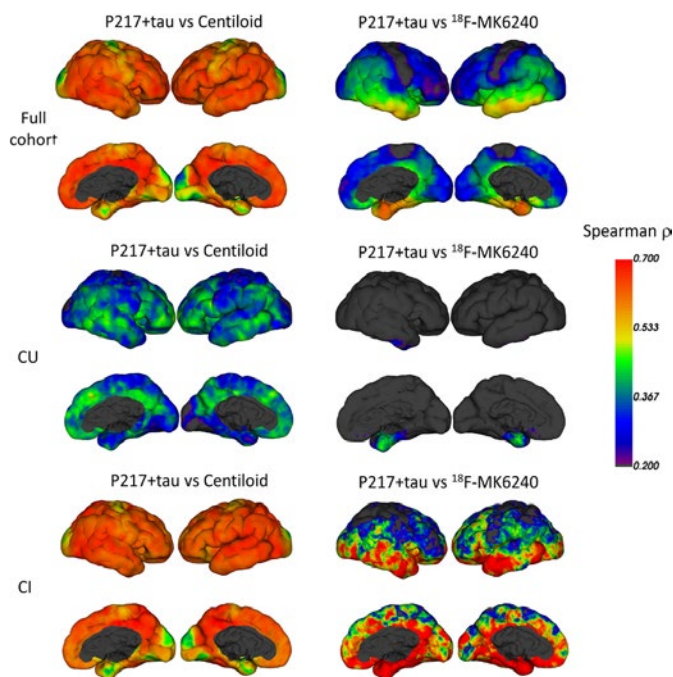
Vertex-based analysis of regional Spearman correlation between plasma p217+tau and centiloid (left column) and 18F-MK6240 SUVR (right column). CU is cognitively unimpaired, CI is cognitively impaired.

Fluid based biomarkers to predict Alzheimer's disease

Collaborator: AIBL Study of Ageing, Biogen, Roche, Eisai, AbbVie, Janssen

Identifying biomarkers for the early prediction of Alzheimer's disease pathology and the cognitive trajectory of the disease are important for treatment and potentially prevention of the disease. In collaboration with several pharmaceutical companies, we are assessing a range of potential biomarkers for predicting AD pathology and progression.

Our research focusses 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. Our work with Biogen was used as background for their FDA application for the first treatment for AD. We are working with the world's largest pharma and industry partners to determine an optimal blood test for AD. Shown below is an example of a blood-based biomarker to predict the AD pathology.
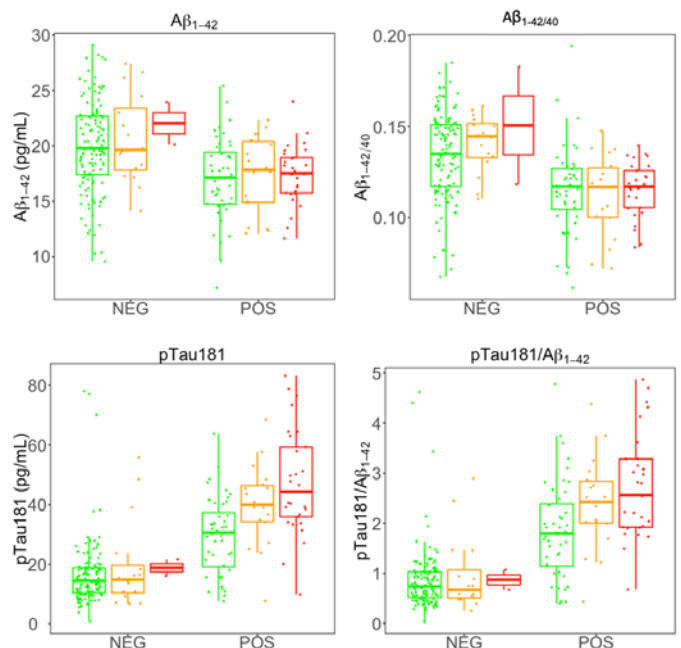
Example blood-based biomarker data to separate PET Amyloid positive participants from PET amyloid negative participants. Top Left: blood based AB42 (y-axis) vs PET amyloid groups (NEG = amyloid negative, POS = amyloid positive) (x-axis). Bottom Left: blood based pTau181 (y-axis) vs PET amyloid groups (x-axis). Top Right: blood based AB42/40 ratio (y-axis) vs PET amyloid groups. Bottom Right: blood based pTau181/AB42 ratio (y-axis) vs PET amyloid groups. Green represents those who are Cognitively normal (CN), orange represents those who have Mild Cognitive Impairment (MCI), and red dots represent those who have Alzheimer's disease (AD).

Biostatistics for Alzheimer's disease biomarker identification

Collaborators: AIBL Study of Ageing, Biogen

Alzheimer's disease has a long lag period between the onset of pathological changes and clinical symptoms. The Australian Imaging, Biomarkers and Lifestyle (AIBL) study of ageing is focused on identifying biomarkers to detect disease pathology prior to the onset of clinical symptoms.

The Biostatistics team contributed to a five-cohort-wide international collaboration to understand the underlying disease aetiology of Alzheimer's disease and provide information to Biogen for the FDA application for their drug Aducanumab. We selected participants from the AIBL study that met the strict admission guidelines for Biogen's two clinical trials. Their imaging and cognitive biomarkers related to change in the Mini Mental Score Examination (MMSE) and Clinical Dementia Rating (CDR) score were assessed. Using results from AIBL and the other four cohorts, Biogen was able to formulate a better understanding of Alzheimer's disease. Using this knowledge, Biogen were 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.
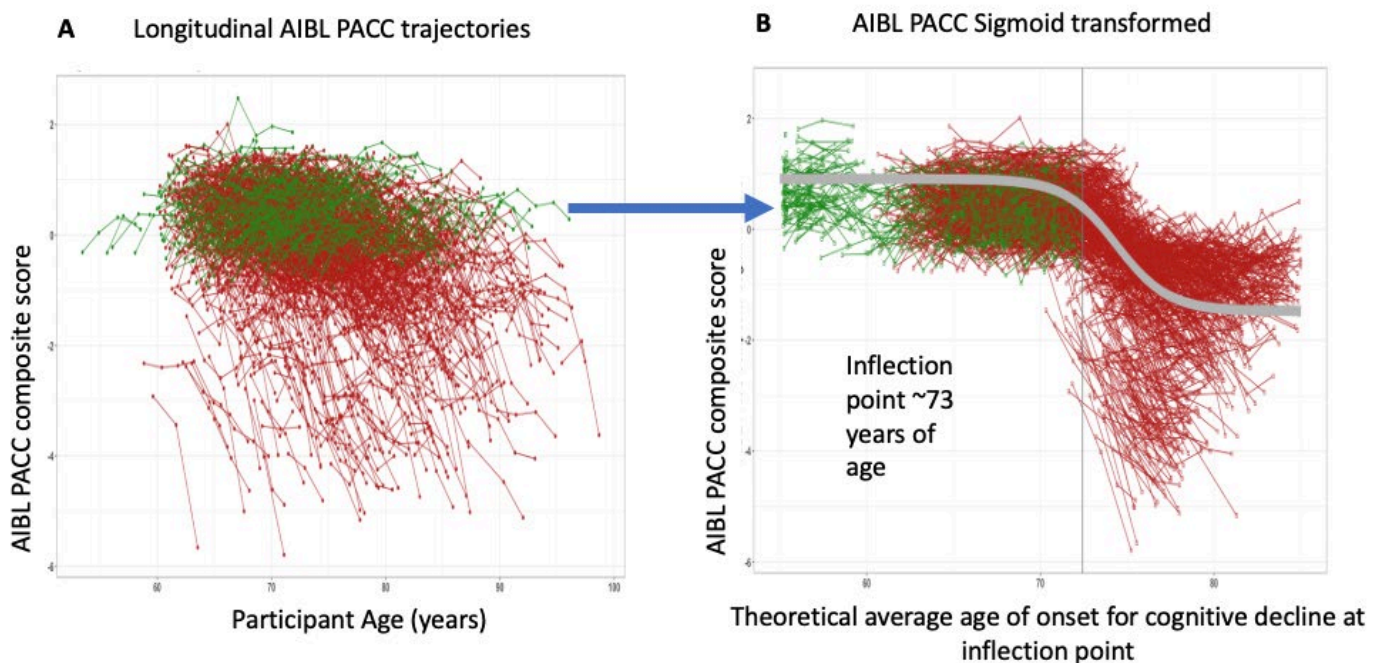
A. Longitudinal trajectories for the AIBL PACC cognitive composite score. Red lines indicate participants classified as having accelerated cognitive decline, green line represent participants classified as stable cognition. B. AIBL PACC sigmoid transformation to yield mean age of onset of cognitive decline. Vertical grey line indicates point of inflection where cognition begins to decline.

Biomedical Informatics: postdoc and student highlights

Postdoctoral fellows

Maria Antico, CSIRO Early Research Career Fellow

Real-time 3D reconstruction from wearable ultrasound system for enhanced imaging

Collaborators: Queensland University of Technology, Neubotx, Technician Training Australia, Fraunhofer Institute for Photonic Microsystems

The project uses advanced AI and image analysis methods to develop a wearable ultrasound system that can create real-time 3D reconstructions of a designated area of interest. The system includes multiple miniaturised automated ultrasound probes to ensure fast and precise reconstructions. The overarching objective is to design a cutting-edge, user-friendly tool that can significantly improve the diagnosis and treatment of medical conditions in various clinical environments (see figure below).
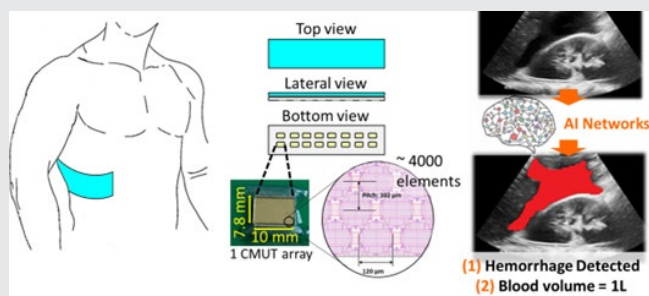
Example of potential application of our technology for automated detection of thoracic haemorrhage (from left to right, the Wearable Ultrasound System positioned on the Morrison's pouch; the design of the device including multiple miniaturised ultrasound probes and an ultrasound image example showing automated haemorrhage detection).

In recent months, we have progressed in the development of algorithms for creating volumetric reconstructions from multiple ultrasound views and acquired datasets through a new collaboration with the Royal Marsden Hospital (England). We have strengthened our collaborations with national and international partners and applied together to multiple funding schemes, including the Defence Innovation Hub and Australia's Economic Accelerator Seed Grant.

We have achieved several milestones, including successful grant applications, invited presentations, and the completion of the On Prime program.

Javier Urriola, CSIRO Early Research Career Fellow

Validating a novel clinical marker of brain age using neurophysiological methods

Collaborators: South Australian Health and Medical Research Institute, Swinburne University of Technology

Brain age, the discrepancy between chronological age and predicted biological age, has gained traction as a marker of brain health. This objective marker could potentially identify individuals at risk of cognitive decline and assess the efficacy of brain health interventions. We used electroencephalography (EEG) and magnetoencephalography (MEG) to analyse over 70 older adults (55-75 years) with memory complaints.

We aim to link brain age predictions to cognitive function and compare and validate brain age across EEG and MEG. We leverage state-of-the-art deep learning techniques to decode the data, analysing the impact of interventions on brain age trajectories and cognitive outcomes.
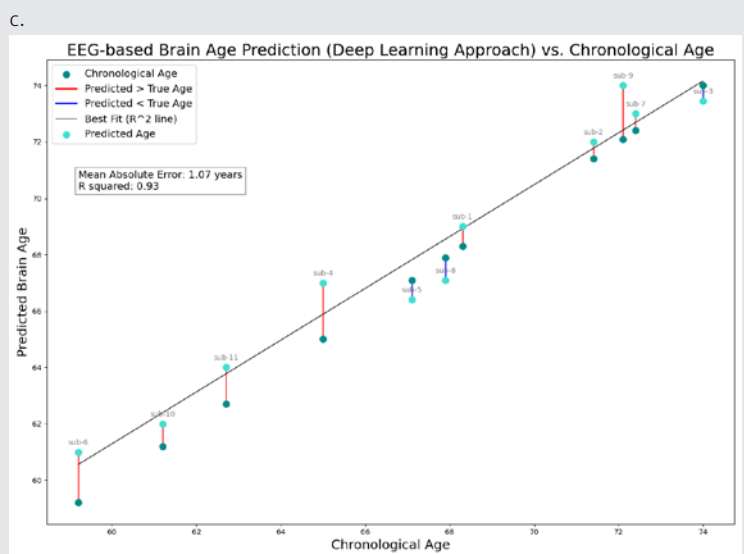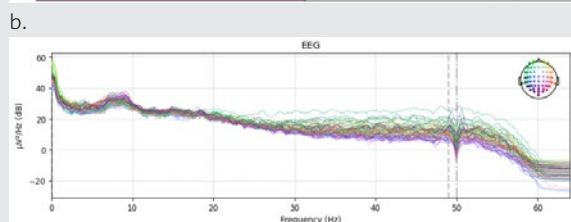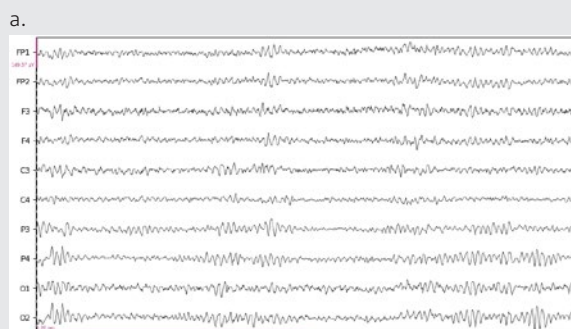
a. Scalp-electroencephalographic (EEG) data are obtained from each participant. b. The procedure for EEG pre-processing before implementing deep learning analysis. c. A visual representation comparing EEG-based brain age predictions to chronological age using the deep learning methodology. Here, every dark dot signifies an individual's true chronological age. The joined coloured lines show the deviation of the predicted brain age from the actual age. Bright dots highlight the model's brain age predictions for each participant. Metrics, including the mean absolute error (MAE) and the coefficient of determination (R squared), offers a quantifiable measure of the model's accuracy. The overarching aim is to evaluate if targeted clinical strategies have a positive effect in decreasing the predicted brain age.

PhD Students

Hilda Chourak

Synthetic-CT quality assessment for MRI-based treatment planning in radiation therapy
Collaborators: University of Rennes, France

Magnetic resonance imaging (MRI) is widely used for cancer diagnosis and offers superior tissue contrast without the need for ionising radiation. This imaging modality holds significant potential for precise delineation of the target volume and organs at risk in cancer treatment. MRI has gained particular interest in external beam radiotherapy, especially with the recent development of MRI-linac machines that integrate an MRI scanner with a linear accelerator. However, a key limitation of MRI is its inability to provide electron density information, which essential for accurate dose calculation. There are several methods, some now commercially available, to provide this information, but the integration of MRI into the radiotherapy workflow faces a major challenge – the lack of standardised assessment metrics. This research primarily investigates areas where synthetic CT generation from MR images tends to be less accurate and proposes strategies to assess the quality of daily generated sCT. These strategies are intended to be included in the clinical workflow to ensure the safe application of MRI-only techniques.
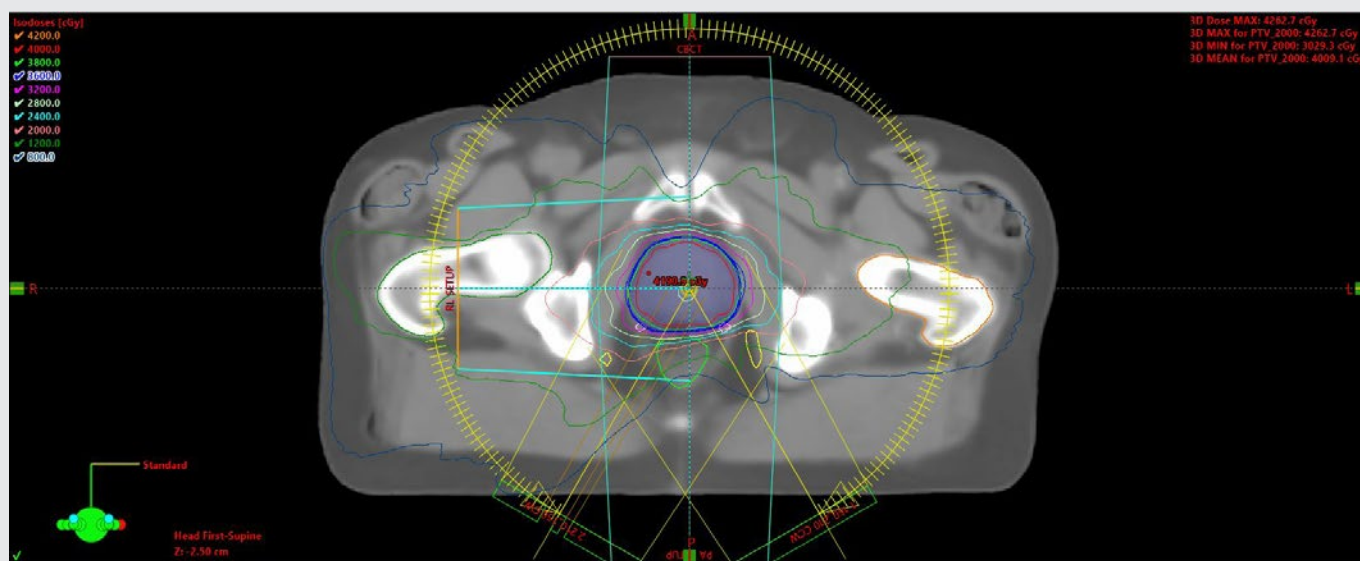
Axial view of the 3D treatment plan for prostate cancer.

The Digital Therapeutics and Care group

Group Leader:
Dr Marlien Varnfield

Our research scientists, technicians and engineers provide evidence-based interventions, driven by high-quality software programs, to improve the delivery of care services to older people, people living with disability, and those with chronic health conditions. We leverage emerging sensor systems, smart devices, and digital technologies to collect individualised physiological parameters, behaviour, and social patterns from a variety of sources.

Digital Therapeutics and Care (DTaC) science and impact highlights for 2022/23

- We completed the 2nd phase of the Care Assistant and support Program for people after Stroke or transient ischaemic attack (CAPS). This stage included a feasibility study where consumers and clinicians used our new platform (mobile app and clinical portal) to support secondary prevention of stroke.

- We completed the roadmap to the implementation of the AI-enabled Assistive technology framework with the NDIA and industry representatives. The framework is now available on the NDIS website under Markets and Innovations Research.

- M♡Ther, our platform for the management of gestational diabetes, has benefited >6000 women since June 2020. The platform has also been utilised for the management of hypertension during pregnancy in multiple NSW hospitals.

Artificial Intelligence in DTaC team

Team Leader: Dr Shaun Frost

The Artificial Intelligence in DTaC team develops diagnostic and decision support systems for remote delivery of health services. Our multi-disciplinary team combines expertise in clinical research, telemedicine systems and artificial intelligence for medical image and data analysis. We work with key stakeholders and collaborators to develop and trial these solutions to promote improved health outcomes and health service delivery.

Emerging Technologies in DTaC team

Team Leader: Dr David Silvera

With wireless sensors, mobile technologies and health technologies increasing in prevalence, new, rich sources of data are now available to determine the influence of lifestyle on health and wellbeing. The Emerging Technologies in Digital Therapeutics and Care team uses internet-connected sensors, robots, and smart devices to facilitate improved outcomes for health, aged care, and disability. We are empowering people to live longer in their homes and supporting their carers and service providers.

DTaC Project Support Team

Team Leader: Liesel Higgins

Our team supports the wider group with project governance, research design development, and practical implementation of projects. The Project Support team consists of research technicians, project managers, and research scientists, all of whom have clinical backgrounds. The team uses their multi-disciplinary knowledge and experience to assist with stakeholder liaison and management, interpretation of health and social care related research problems and projects, and strategic development of research projects. Collectively the team contribute to research design and development, project evaluation, research analysis, data management, application to ethics and privacy governing bodies, project timelines and accountability of project deliverables.

DTaC Insights team

Team Leader: Janardhan Vignarajan

Our team comprises of scientists and engineers with expertise in public health and health services, software engineering and machine learning. We are developing, trialling and validating new models of care in mobile health, tele-health and virtual care settings.

DTaC Indigenous team

Team Leader: Dr Georgina Chelberg

Committed to increasing our contribution to addressing the health disparities between Indigenous and non-Indigenous people in Australia, we partner with Aboriginal and Torres Strait Islander community-controlled organisations to co-design and co-develop e-health solutions to complement existing successful models of care for some of the most significant health issues in their communities.

Central to the vision and research activities of the Indigenous Health team is the understanding that Indigenous people conceptualise health as holistic, dynamic and interconnected—as opposed to the dominant mainstream model on which many health interventions are based. In 2023 the Indigenous Health team at AEHRC were integrated within the Digital Therapeutics and Care (DTAC) group. In 2022–2023 the Indigenous Health team have continued the work of several existing projects as well as establishing new projects, these include leveraging CSIRO technology to challenge the health disparities within Australia.

Digital Therapeutics and Care: 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 wireless sensor and monitoring technologies 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 evolved via several pilot studies since 2013 and is now progressing into the internet of robotic things space, where supporting intervention is incorporated in addition to data monitoring. The SSH platform technology readiness is at TRL 8, has been licensed to an Australian ASX listed company, and currently being integrated within a commercialised aged care platform and service offering.

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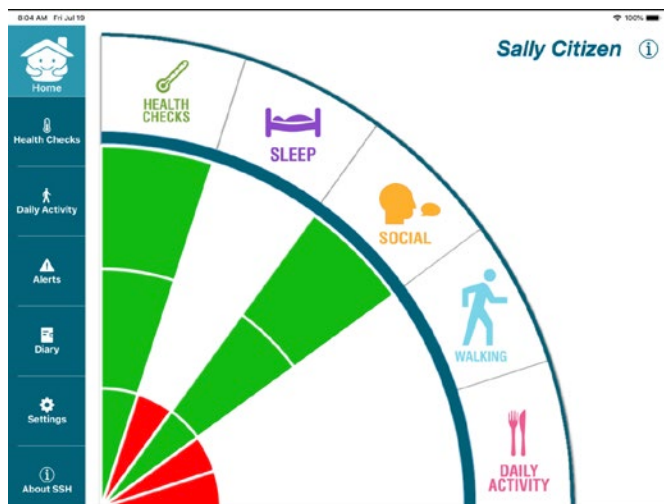
The SSH mobile application enables residents to view data derived from the sensors and medical devices.

Mobile health platform

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

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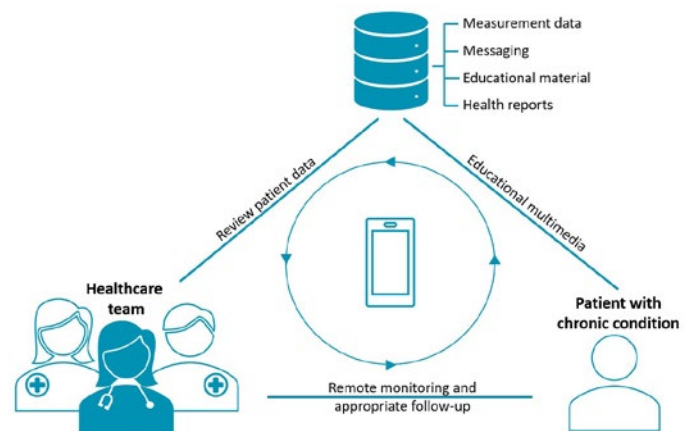
Components of the mHealth platform and data communication.

Mobile health platform on FHIR

Our mHealth platform is undergoing a redesign with personally controlled health information, self-management and interoperability in addition to the existing platform features. The FHIR based architecture is not just a FHIR shim or a FHIR server in the backend. We are working to solve the issues around 3rd party FHIR server integration and correlation of existing patient identity while maintaining the patients' control over where their data goes, be it a primary care system, hospital system or other FHIR server like a health data exchange. The new platform will also expand our reach to self-management of general health and chronic disease, primary care intervention and pre and post hospital monitoring and rehabilitation, potentially covering the entire patient journey.

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

The MICE app image review.

Remote-I: store and forward telehealth platform

Australian e-Health Research Centre has pioneered a cloud-based information management system comprised of clinical data management, web access from mobile and desktop, and a store-and-forward document handling system. The platform's flexibility has enabled us to test it across multiple healthcare domains including tele-dentistry, remote eye care and burns and wounds imaging. In delivering eye health to remote and rural population, the platform has been customised and deployed in northern Australian remote communities, read more in the Health Services: Project Updates section.

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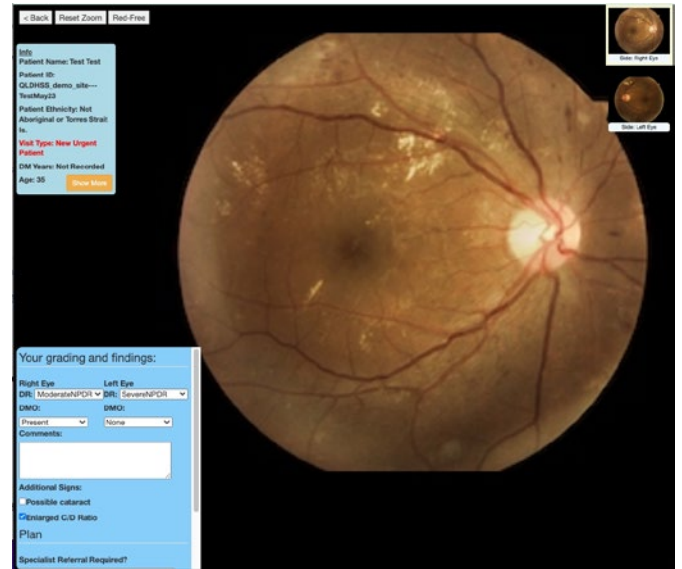
Remote-I – Eye Specialist Review Screen.

SIANNO: Simple Image ANNOtation Platform

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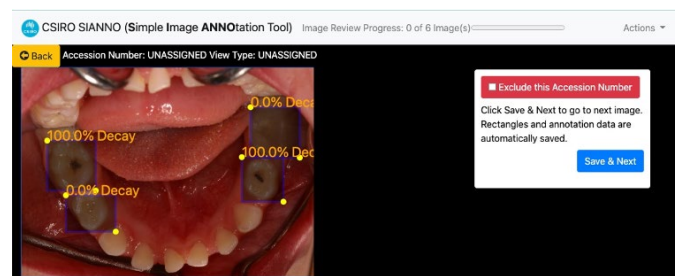
AI detection integrated into SIANNO tool to detect dental caries.

Digital Therapeutics and Care: project reports

M♡THer studies

Collaborators: Metro South Hospital and Health Service, Metro North Hospital and Health Service, Mater Mothers' Hospital, Cairns Hinterland and Hospital Health Service, South Western Sydney Local Health District, Western Health and Monash Health Melbourne

Gestational diabetes mellitus (GDM) and hypertension are two of the most common conditions of pregnancy with the incidence and prevalence of both conditions increasing over recent years due to changing diagnostic thresholds and an increased cardiometabolic risk profile amongst the population. The conditions are resource intensive, placing considerable demands on both the mother and health system due to their chronic nature and multidisciplinary management requirements. In 2017 we co-developed the 'M♡THer platform' with the Redland Hospital to address some of their challenges providing GDM management to a growing population.

In collaboration with the maternal diabetes clinic, we developed a platform that could support an individual to log and track their health data (blood glucose, blood pressure, steps, stress, sleep etc) and facilitate remote monitoring by the multidisciplinary team. The platform

consists of a patient facing app and a web-based clinician platform. A successful feasibility study led to a multisite implementation study, buoyed by the demand for remote-monitoring during the COVID-19 pandemic. Since mid-2020, the GDM platform has supported over 6000 women and their health care team, with studies operating across Redland l, Logan, Mater, and Royal Brisbane and Women's Hospitals. Additional feasibility studies have also been undertaken in regional and remote areas, including a past study at Mt Isa Base Hospital and an active study at Cairns Hinterland and Hospital Health Service (inclusive of Innisfail Hospital, Mareeba Hospital, and Mossman Hospital). Data and the continued demand for the platform suggests mHealth supported GDM management is an effective tool for women and their health providers in managing GDM. A step-wedged trial will be commencing with two Melbourne health services to explore if and how the mHealth supported model of care for GDM can positively affect clinical outcomes.

Inspired by the opportunity to provide quality care remotely, easing the resource burden associated with frequent face to face appointments for hypertension in pregnancy, South Western Sydney Local Health District sought to augment the platform to manage hypertensive disorders in pregnancy. A randomised control trial is nearing completion across three hospitals in Sydney and will provide insight into the effectiveness of remote monitoring for maternal hypertension management.

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

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

Collaborator: AI4Path

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

Prostate cancer is the second most common form of cancer in men, with more than 1 million new diagnosed cases worldwide every year. In recent years a significant demand to develop computer-assisted diagnostic tools to assess prostate cancer using whole slide images has been observed. In this study we develop and validate an ML system for cancer assessment. The system analyses the whole slide image in three consecutive stages: tissue detection, classification, and slide level analysis. The whole slide image is divided into smaller regions (patches).

The tissue detection stage relies upon traditional machine learning to identify WSI patches containing tissue, which are then further assessed at the classification stage where deep learning algorithms are employed to detect and classify cancer tissue. At the slide level analysis stage, entire slide level information is generated by aggregating all the patch level information of the slide. A total of 2340 haematoxylin and eosin stained slides were used to train and validate the system. A medical team consisting of 11 board certified pathologists with prostatic pathology sub-speciality competences working independently in 4 different medical centres performed the annotations. Pixel-level annotation based on an agreed set of 10 annotation terms, determined based on medical relevance and prevalence, was created by the team. The system achieved an accuracy of 99.53% in tissue detection, with sensitivity and specificity respectively of 99.78% and 99.12%. The system achieved an accuracy of 92.80% in classifying tissue terms, with sensitivity and specificity respectively 92.61% and 99.25%.
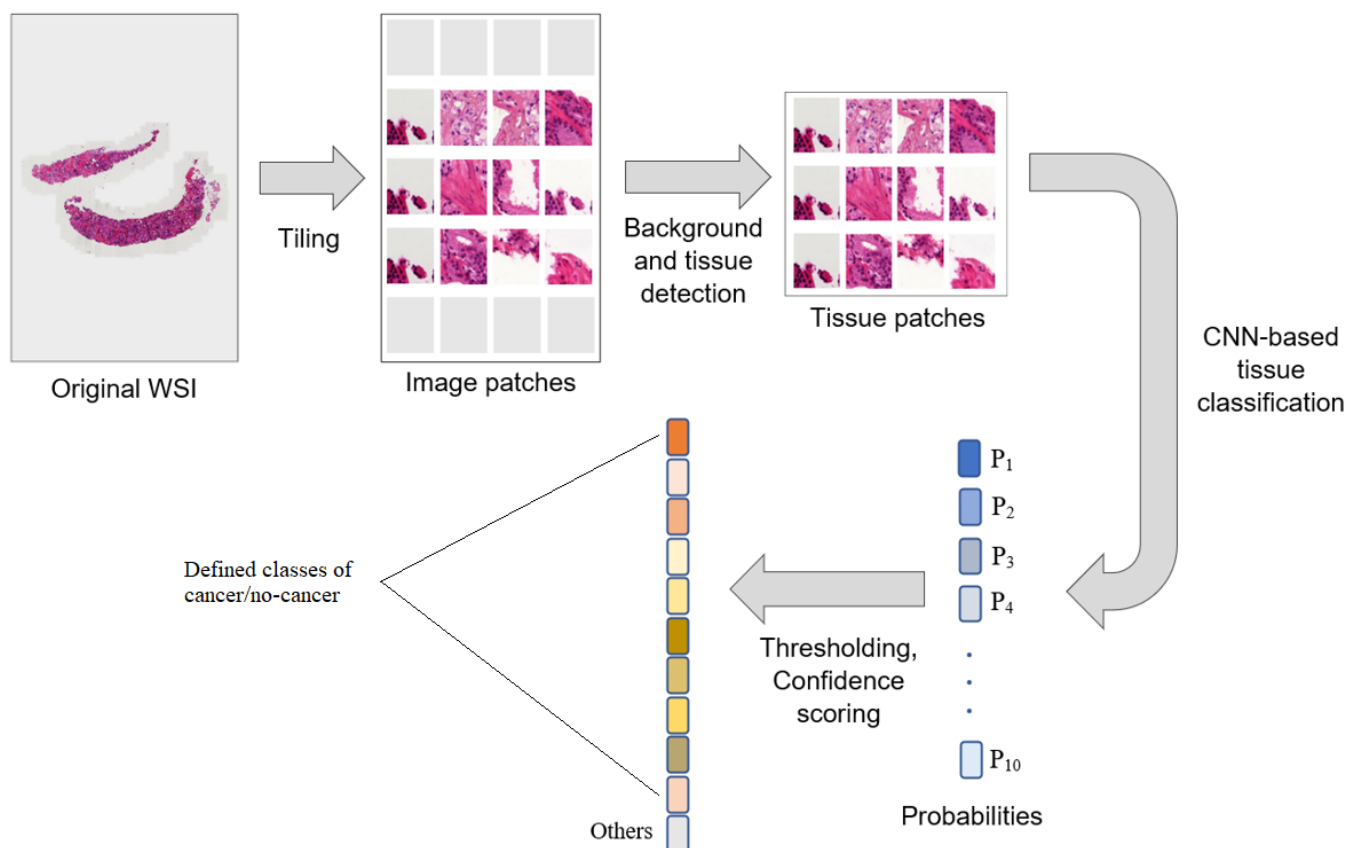
The process of classifying a whole slide image (WSI) with the proposed system.

Redefining eye-health delivery in underserved population

With a lack of eye specialists in rural and remote regions around the world, and with the increasing prevalence of diabetes and other chronic conditions related to eye diseases, delivering efficient digital eye care service to underserved populations is key to reducing the burden of preventable eye diseases. We have been working with multiple stakeholders in remote eye care delivery since 2009.

In the Australian context, we are working with Queensland Health's Telehealth Unit, Royal Perth Hospital in Western Australia and other healthcare providers towards streamlining eye health service delivery by deploying a secure cloud-based platform (Refer Platform Page link here). The programme covers Northern Australian remote regions and Royal Perth Hospital.

Globally, during 2022–2023, we partnered with The Fred Hollows Foundation to identify the gaps in deploying efficient diabetic retinopathy screening and other eye health service delivery in Vietnam and explored the potential of AI-based screening systems to be adopted in such settings. The team translated the existing telehealth platform from English to Vietnamese and worked with the partners to identify implementation pathways. The project was funded by the Department of Foreign Affairs and Trade and won the World Health Organisation's Innovation for Impact Challenge in 2022.

The group is now in discussion with various stakeholders towards sustaining such services across the regions.

CSIRO's eye health platform translation into Vietnamese: patient record page.

New Project: Internet of robotic things to support independent living

Collaborators: CSIRO's Data61

As we grapple with an increasingly aging population and a decline in the aged care workforce, there needs to be a paradigm shift in aged care, to promote autonomy and independence, prevent social isolation, and fosters physical and cognitive well-being in older Australians. This project aims to develop internet of robotic things (IoRT) solutions to support independent living of older adults and people living with a disability (PLwD). It employs internet of things (IoT) sensors to monitor the health and activities and use social and care robots to provide real-time support (Figure 1). These technologies can be combined to build a smart home for older adults that continuously monitors the activities of people, alerts caregivers in case of an emergency, and provides end users with practical support.

In the initial stage of this project, we are working with aged-care partners to better understand the needs, requirements, and preferences of end-users and their caregivers. We are also working on new smart home architectures, involving cloudless computing and AI integration (e.g. federated learning strategies), to make this system effective. The proposed IoRT based smart home will promote more active and healthy lifestyles of older adults, while living independently in their own homes. It will improve overall quality of life and reduce national healthcare expenditure.

IoRT based smart home can enable independent living for the older adults and PLWD by monitoring their health/activities and providing real-time support.

Roadmap for AI-enabled AT Framework for the National Disability Insurance Scheme – Industry Engagement

In May 2022, we developed a principles-based evaluation framework (the Framework) and roadmap to implementation (the Roadmap) to guide the National Disability Insurance Scheme (NDIS) stakeholders through the development, testing, and implementation of AI-enabled assistive technology (AT). To progress this work, this year we completed a workshop for industry stakeholders to explore the anticipated benefits, potential risks and perceived challenges to the implementation and uptake of the Framework in Australia. Discussions focused on strengths, weaknesses, and gaps in the Framework and Roadmap.

Overall, workshop contributors identified several advantages of AI-enabled AT for people with a disability and agreed that the areas covered by the Framework were appropriate. They also reiterated the Framework's value in supporting the assessment of AI-enabled AT and ensuring that industry gave due consideration to each of the domains when developing new products. In addition, contributors provided feedback on the Roadmap and highlighted the need for an inclusive governance body and a cyclical roadmap to allow for iterative improvement.

The framework is available via the NDIA website: https://www.ndis.gov.au/news/8492-framework-artificial-intelligence-enabled-assistive-technology-supports-under-ndis

CAPS (Care Assistant Platform for Stroke): Feasibility study

Collaborator: Monash University

We designed and developed a Care Assistant and support Program for people after Stroke (CAPS) or transient ischaemic attack (TIA). The CAPS program spans 12 weeks and is delivered virtually. It features a mobile app and wearable devices for patient data collection, a web-based clinician interface for health monitoring and alerts, clinician-facilitated goal setting, and tailored SMS messages to support goal achievement. A feasibility study using mixed methods design has been conducted with 33 individuals who had experienced stroke or TIA. The preliminary findings showed small-to-medium improvements in self-efficacy, global health (mental and physical domains), as well as reductions in depression and anxiety. Qualitative interviews with 10 study participants and 10 clinicians further supported the feasibility of CAPS as a secondary prevention program. This novel CAPS program has the potential to be implemented as a clinician-led digital program to enhance the existing multidisciplinary secondary prevention programs offered in hospital, allied health, and GP services. The CAPS program will be refined, before it progresses to a Phase II feasibility clinical trial.

NEW Project: Digital yarning using interoperable computer integration for sharing medical records and photographs to close the gap

AEHRC is one of the ten recipients of the Ministers Innovation Challenge in Western Australia. With its collaborator South Metropolitan Health Service in Western Australia, CSIRO will develop a proof-of-concept project showcasing the capabilities of integrated digital health, especially focussing on the remote region of Pilbara, Western Australia. The project will liaise with local Aboriginal health service stakeholders in a collaborative environment and is aimed at producing a long-term interoperable proof of concept solution to connect various service providers through open health standards and demonstrate the implementation of such solutions.

With its partners, the team is exploring the use of interoperable standards in the healthcare and developing solutions tailored to specific needs of the health sector in the Pilbara region. This project is supported by the Western Australian Department of Health though the Future Health Research and Innovation Fund and keystone partners Rio Tinto and BHP.
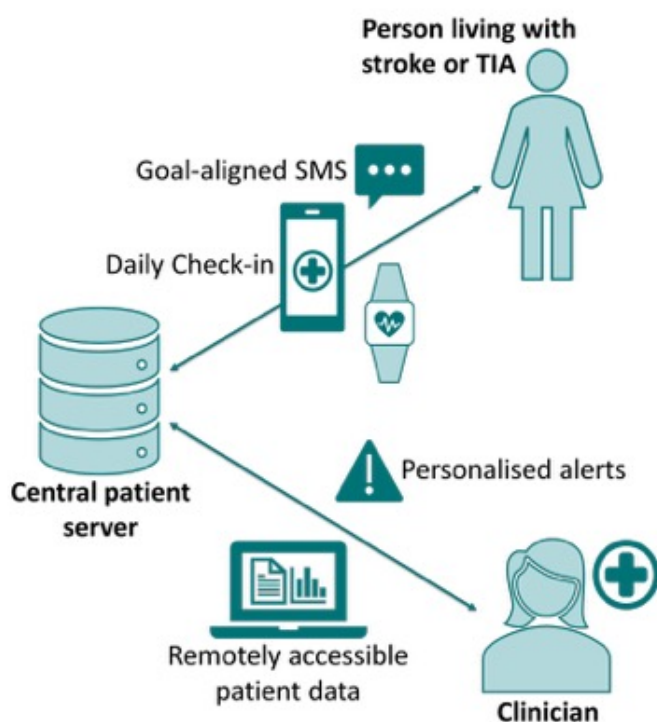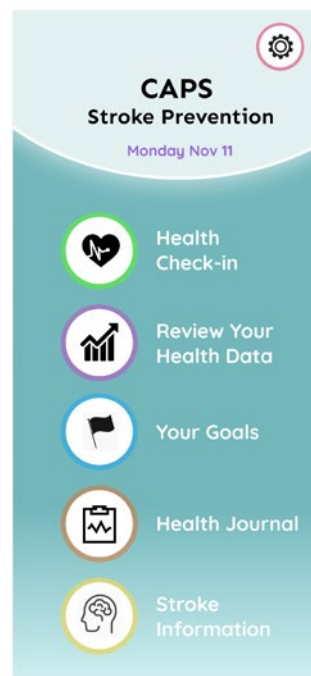
CAPS program and app home screen.

Digital Therapeutics and Care: project updates

Rehabilitation for pulmonary disease (m-PR)

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

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

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

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

HAPPI MIND

Collaborator: Monash University

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

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

MoTER-HF heart failure platform

Collaborator: The Prince Charles Hospital

We have developed an interactive digital platform to support patients with heart failure in their self-management of the chronic condition. The platform is based on AEHRC's mHealth technology and consists of a smartphone app for patients, as well as a web-based portal for clinicians. It has been iteratively co-designed with patients and clinicians at the Heart Failure Services at The Prince Charles Hospital (TPCH). Technical, clinical, and practical factors associated with the platform's use have been carefully considered in the development process. The features of alerts for supporting clinician data monitoring and reminders for supporting patients' daily symptom and health measure monitoring have been incorporated into the platform. A feasibility study using mixed method design will be conducted with the patients with heart failure at TPCH.

Feasibility Study of posture detection and human identification based on radar sensing

Collaborator: University of Queensland

It is often recommended office workers to take regular 'stretch' breaks both for psychological health and for the prevention of musculoskeletal disorders including repetitive strain injuries. The primary goal of this project was to develop signal processing and machine learning techniques for the identification of stretch behaviours using ultra wideband (UWB) radar data. Various data processing approaches were explored to extract both distance and Doppler frequency shift information. The proposed deep learning model consists of two parallel sets of convolutional layers, taking both distance and Doppler images, with a test accuracy of 93%. The signal processing and deep learning model can run in real time, using a small Raspberry Pi computer. In the upcoming phase, our focus will shift towards radar-based multi-person detection and identification, which is a common challenge in smart home context.

New Project – Fall prevention in residential home via distributed sensors – BEST CARE project

In March 2023, we were awarded an Aged Care Research and Industry Innovation Australia (ARIIA) grant in a collaboration with HSC Technology Group, to understand if distributed ambient sensors can be used to successfully reduce the number of falls occurring within a residential aged care home environment. The long-term objective is to use a combination of sensors placed around the residential aged care home with settings adjusted to individual risks to identify factors that can lead to a fall. This study will explore the acceptability of these autonomous sensors and the use of an individual's 'sensor story' to understand a person's wellbeing. The study will also aim to identify any barriers to adoption and the impact of this technology on the aged care organisation's operations. Ethics and privacy applications are currently in process and the study is due to be finished by March 2024.

Retinal image reconstruction in optical coherence tomography

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

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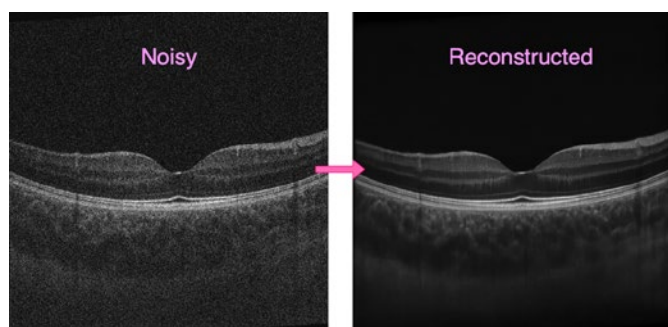
A noisy image reconstructed using our technology

Retinal imaging for cardiovascular risk assessment

Collaborator: Dobney Hypertension Centre, Royal Perth Hospital

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

CSIRO have developed AI to detect and grade retinopathy automatically from retinal photographs and compared CSIRO-developed with commercially available deep learning systems. Our results have improved understanding of the performance and limitations of these systems and helped inform optimal clinical workflow.
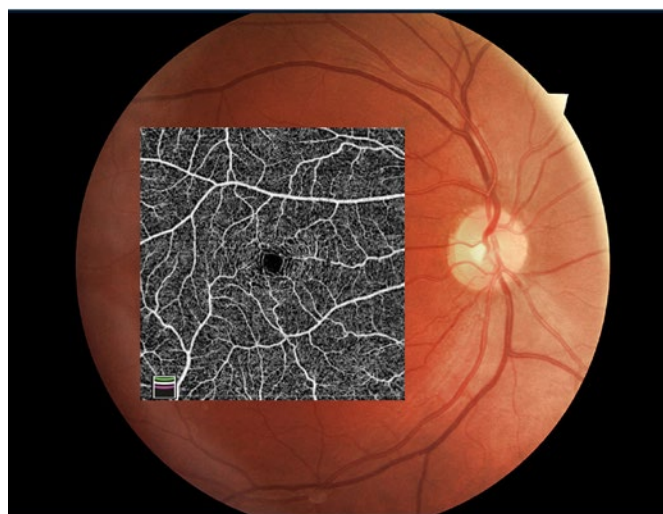
Optical coherence tomography angiography image of the retina.

Electro-encephalogram monitoring in depression

Collaborator: Resonait

In Australia, one in seven adults are expected to experience depression at some point in their life and the burden of this disease in this country has been measured to be the third highest, as measured by financial cost, mortality and morbidity. One of the greatest challenges in addressing this burden is the lack of access to mental health professionals and treatment, which are worsened by ever increasing waiting times.

Through a kickstart grant, CSIRO are collaborating with Resonait, an exciting Australian startup, to validate their technology towards developing a new medical device to manage and treat depression to augment and support psychologists in their clinical practise. By combining wearable brain sensors and neuromodulation, this device will utilise AI algorithms to adjust stimulation (audio-visual and/or magnetic) based on individual brain patterns through neurofeedback. Using a public dataset, CSIRO analysis have already demonstrated exciting preliminary results evaluating the performance of Resonait's algorithm. Additionally, Resonait in collaboration with The Black Dog institute are currently conducting a pre-clinical trial with this technology, where CSIRO will continue to assist with the data analysis.

Resonait are developing a neurofeedback device to detect and modulate the default-mode-network, particularly relevant to depression as it is often a brain state associated with rumination.

AI in dental images and radiographs

Funder: WA Health Research and Innovation Office

We have developed a suite of AI models to detect dental caries and tooth numbers from dental radiographs (bitewing and panoramic x-ray images) and colour dental photographs. Data for the project was collected from various clinics across the Perth region. Several deep learning-based artificial intelligent feature detection models were developed and tested against the dataset. Calibrated dental specialists were involved in labelling the data. Recently, the team presented their work at MedInfo 2023 where a deep learning-based detection model was developed to detect tooth caries in colour dental images which has reached an accuracy of 79% using the Inception-v3 network. Further validation of such models in large datasets is being explored.

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

Collaborator: University of Minnesota

Funded by the International Association of Dental Research (IADR), we're collaborating with the University of Minnesota to determine the efficiency of the tele-dental and mobile-dental models of care in urgent dental trauma care. The project will capture data and photographs of dental trauma cases from the United States of America and Thailand hospitals using smartphones through the mobile app (CSIRO-developed technology). The photographs are being reviewed by multiple dental therapists using CSIRO's web-based tele-dental cloud dashboard and the results will be compared with the on-site dental specialists' outcomes. The project started in 2022 and is scheduled until 2023.

Diabetes-related foot ulcer risk detection device

In Australia, an estimated 1.2 million (6%) adults are living with Diabetes Mellitus (DM), a complex and challenging condition to manage. Diabetes-related foot ulcers (DFUs) are a major, but frequently underappreciated, complication estimated to affect approximately 30% of people with diabetes over the course of their lifetime. Over half of DFUs are reported to develop an infection, of which, 17% result in amputation. Once more, the 5-year mortality rate for persons who have a major lower extremity amputation due to DFU is greater than 50%. Proper surveillance and early identification are therefore essential to prevent possible ulcer formation and the associated morbidity and complex healthcare management challenges.
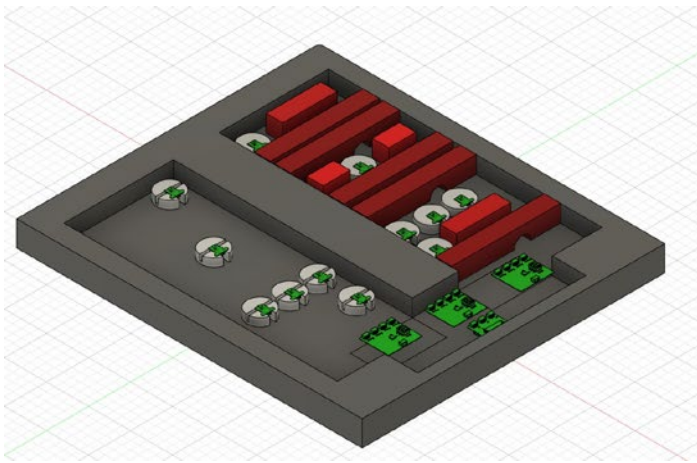
Through an iterative design process, the hardware (left) and wireframes (right) of the prototype continue to develop.

After being awarded the 2022 TRI – CSIRO AEHRC grant, the team continue to finalise the prototype, which is currently undergoing functional testing. Furthermore, the project is preparing documentation, ethics, and a research plan to conduct a proof-of-concept trial in collaboration with Queensland Metro-South, QUT, La Trobe University, Goulburn Valley Health, Diabetes Feet Australia, and The Townville University Hospital.

Through an iterative design process, the hardware (left) and wireframes (right) of the prototype continue to develop.

Design and Evaluation of a clinical decision support system for managing COPD

Collaborators: Lung Foundation Australia, University of Melbourne

Addressing the disease burden of patients and improving clinicians' adherence to national guidelines represent challenges in the management of chronic obstructive pulmonary disease (COPD). The national COPD guidelines, known as the COPD-X plan, are published and updated by the Lung Foundation Australia, offering evidence-based practical recommendations for clinicians regarding the diagnosis and management of COPD. The poor uptake of these guidelines by clinicians has created a significant gap in COPD practice, resulting in suboptimal patient management.

The AEHRC is collaborating with the Lung Foundation Australia and the University of Melbourne to design, develop, and evaluate an innovative digital platform aimed at supporting efficient decision-making for clinicians in COPD management, thereby improving the adoption of guidelines in clinical practice. This project will employ a co-design approach in the design process, incorporate an easily accessible and interactive digital solution to translate clinical guidelines for COPD care in the hospital setting, and utilize principles from implementation science to ensure the effective translation of the digital intervention.

Wearable sensors for energy expenditure measurement in patients with burn injury

Collaborator: Royal Brisbane and Women's Hospital

Severe burns cause a profound pathophysiological stress response and a radical increase in metabolic rate. Current methods for determining energy expenditure (EE) in patients with burns have poor accuracy. This project aims to identify the primary physiological indicators of EE and explore how they can be measured non-invasively using wearable devices. A review of the literature, market research, and consultation with relevant stakeholders were was undertaken to identify promising wearable technologies capable of measuring physiological indicators of EE. A feasibility trial will be conducted to evaluate these sensors. These devices will gather physiological data, enabling the estimation of total EE through standard estimation equations and iterative algorithms, which will be compared against the gold standard measurement for EE in a clinical setting (indirect calorimetry). This research will provide valuable data to improve our understanding of the potential use of wearable devices to monitor EE to guide nutrition decisions.

Artificial intelligence and smartphone-based system for assessment and monitoring of glaucoma at home

Glaucoma is the leading cause of irreversible blindness worldwide. Routine screening, especially for people who are at risk, is crucial to prevent vision loss in glaucoma. However, screening services can be challenging to provide in remote locations and for those who are less mobile. This project aims to address this by bringing eye screening into the home, developing and validating an artificial intelligence and smartphone-based system for assessment and monitoring of glaucoma. This AEHRC project is currently funded by the WA Department of Health.

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

Collaborator: South Metropolitan Health Service, Western Australia

X-ray imaging of the foot is often used to diagnose diabetic foot infection. Assessment of osteomyelitis infections and its progression using x-ray is a challenging task even for experts. Along with our collaborators, Edith Cowan University and South Metropolitan Health Services, this project aims to analyse over 13,000 radiographs of diabetic foot and develop a deep learning-based AI model for determining the presence of osteomyelitis and toe amputations. A model has now been developed to detect toe bone numbers from a radiograph and is now being integrated into continuous research. Funded by the Department of Health, WA, the project activities cover automated extraction of information from textual x-ray reports for disease conditions and correlate with image pattern recognition to identify the disease. A longitudinal analysis of the progression of the disease will also be explored in the project.

Use and preferences of health apps among women and healthcare professionals regarding GDM postpartum care: a national survey

Collaborators: National Diabetes Services Scheme

Mobile health is well accepted by patients and care providers as a tool to support the management of Gestational Diabetes Mellitus (GDM), yet little is known about the capacity of mobile health to support health and wellbeing postpartum. An experience of GDM increases a women's risk of cardiometabolic disease and the postpartum period is considered a critical window to reduce these risks and support health long-term. The National Diabetes Services Scheme supports a postpartum health behaviour app, BabySteps. However, it is not clear the reach of the app across Australia or if women are actively using it. This study aims to explore postpartum health information and support needs, along with current use of and preferences for health apps, among women with prior GDM and GDM health providers.

Development of digital diet diary for women with gestational diabetes

Collaborators: Metro South Hospital and Health Service

The stabilisation and monitoring of blood glucose levels is a key feature of managing gestational diabetes and reducing health risks posed by the condition. Blood glucose levels are influenced by a number of factors, including the foods we eat. Carbohydrates in food are broken down to glucose affecting blood glucose (sugar in the blood). This project involves developing a digital diet diary within a glucose tracking application (M♡THer) used by women with gestational diabetes. The digital diet diary can be used to monitor and track food consumed, relative carbohydrates, and provide insight on how food is affecting blood glucose. Dietary tracking is thought to not only support the effective management of the condition, but by increasing the awareness of the condition, those affected increase their self-efficacy and perceived control, which can affect behaviour change.

APaIR Virtual Care

The APaIR Virtual Care project completed its second year of a three-year initiative. Drawing from multiple groups across the AEHRC, focus has been on virtual care research across acute care, chronic care, disability, aged care, interoperability, and implementation science. Highlights from this year include the allocation of $9.3million in the Australian Federal Budget for a FHIR accelerator project to better connect health data and improve access to services for customers and health professionals for improved outcomes; the release of the AI-Enabled AT Framework through collaboration with the National Disability Insurance Agency (NDIA); completed evaluation of the 'Living with COVID' service delivered by Healthdirect and findings that it was successful in connecting consumers to appropriate care during the pandemic; development of the digitised eSPICT tool for support in Aged Care with BallyCara and QUT; and build of the Mobile FHIR Interoperable Platform for use in validated Patient Apps/Clinician portals.

Terracotta

Collaborators: Monash University

Targeting Treatable Traits in COPD to Prevent Hospitalisations (TERRACOTTA) will focus on a national roll-out of the interdisciplinary model of care, to inform its scale-up as a routine service. The current study's aim is to demonstrate the efficacy of a practice nurse-coordinated intervention targeting Treatable Traits in moderate-severe COPD in general practice for improving health-related quality of life and reducing hospitalisations/emergency department visits. As a part of this intervention a consumer facing mobile application was developed by CSIRO to provide guided health information and a digitised version of the COPD Action Plan, which allows the research team to collect engagement and real time COPD status information.

Digital Therapeutics and Care: postdoc and student highlights

Postdoctoral fellows

Dr Kaley Butten

Mobile health platforms are becoming increasingly common as health services try to meet the growing demand for quality care in chronic health conditions, yet the implementation process can be challenging. Kaley has been exploring the change management experiences of health providers utilising the M♡THer platform, an App and web-based dashboard, to support the management of gestational diabetes across five Australian hospitals.

Dr Anna Roesler

With a focus on pregnancy, maternal health post-birth is often overlooked. Anna is exploring the needs and values of women and their health providers in the context of GDM post-birth; gaining an understanding of, if and how, digital health can support women and their providers in the 'fourth' trimester.

Dr Moid Sandhu

Moid is working on a 'Smart Home' system to foster the independent living of individuals, with a particular focus on older adults and those with disabilities. His work involves investigating an array of wearable and ambient sensors, aiming to monitor the well-being and daily activities of residents within their homes. Additionally, he is delving into cutting-edge assistive technologies, aiming to offer autonomous and real-time support to individuals in order to enhance their overall quality of life and well-being.

More recently, he has embarked on a project involving distributed and federated learning. This innovative approach serves to address privacy concerns while simultaneously augmenting the reliability of the services offered by the smart home system.

Dr Deepa Prabhu

Deepa is working on using data from wearable and ambient sensors to understand lifestyle, activities, and health behaviours to help develop methods to effectively manage acute and chronic health conditions (including mental health conditions) and maintain functional and cognitive well-being in older age. Deepa has worked on analysing the data from DACS trial to understand correlations between in-home movement patterns (measured using sensors) and depression among older adults living independently in the community. She is also working on an ARIIA funded project aimed at early identification of falls risks using ambient sensors to inform proactive prevention measures in older adults living in residential aged care settings.

Students

Yashodhya Vachila Vijesinghe, Queensland University of Technology

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

Ms Eve Martin, University of Western Australia

Eve has evaluated all 3 TGA approved Deep Learning Systems for diabetic retinopathy grading in a tertiary hypertensive cohort. She found an association between false negative results for diabetic retinopathy and hypertensive severity, and results supporting the value of clinical follow up for false positive results.

Deep learning software applied to colour fundus photographs has potential to efficiently detect retinal anomalies and thereby reduce clinical workforce burden and improve patient outcomes.

Liam Allan, Monash University (PhD Student)

Liam's work focusses around the feasibility, effectiveness, and potential cost-effectiveness of mHealth programs for secondary prevention of stroke. In the past year, he has been involved in all aspects of the CAPS feasibility study, including trial preparation, coordination, and analysis. Additionally, Liam has submitted a review exploring the translation of mHealth interventions for secondary prevention of stroke into real-world use to the journal Stroke (AHA).

M. Nadeem

Nadeem explored various data augmentation techniques to enhance a dataset of physiological measures collected from children on the autism spectrum. By adapting data augmentation techniques initially devised for motion and activity data, he sought to enhance the available physiological data, and improve the performance of machine learning prediction models to detect early signs of emotional dysregulation in children.

AEHRC and Indigenous Health team

Team Leader and Research Officer: Dr Georgina Chelberg

In her team lead role with the Indigenous Health Team, Georgina has co-ordinated digital health projects and partnerships with Aboriginal and Torres Strait Islander Community Controlled Organisations. Georgina has also co-ordinated the Health & Biosecurity Indigenous Appropriation Program to manage and report on eHealth, Human Health and Biosecurity research partnerships with Aboriginal and Torres Strait Islander Organisations

Visiting Scientist and Professor at Flinders University, Adelaide: Professor Ray Mahoney

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

AEHRC and Indigenous Health team highlights 2022–2023

- Dr. Georgina Chelberg completed her doctoral studies and was conferred by the University of Queensland in April 2023. Her thesis is titled 'Digital health to enhance access and delivery of quality care with Aboriginal and Torres Strait Islander people, including persons living with dementia'.

- In June 2023, Andrew Goodman and Prof. Ray Mahoney had a paper published in the JMIR mHealth and uHealth journal titled, Influencing Factors to mHealth Uptake With Indigenous Populations: Qualitative Systematic Review. This is Andrew's first scientific publication.

- In October 2022, the Indigenous Health Team presented the final report to Goondir Health Services on qualitative evaluation results from the InReach Kids Project.

- Ray Mahoney and Andrew Goodman delivered a workshop titled 'Best practice in digital health research with Aboriginal and Torres Strait Islander people' at the 2023 MedInfo conference in Sydney 8th July.

- MRFF 2022 Cardiovascular Health. Ray Mahoney and Andrew Goodman (CIs). Clinical and health economics implications of routine CTCA for emergency department assessment of Aboriginal and Torres Strait Islander people at risk of acute coronary syndrome Georgina attended & presented at the 17th World Congress on Public Health in Rome, Italy 'Culturally safe eHealth: what is 'best practice' and who determines it?

- Andrew Goodman submitted PhD thesis titled: Can an integrated mHealth platform assist in the management of hypertension for Aboriginal and Torres Strait Islander people? to The University of Queensland April 2023.

- Andrew Goodman was successful in securing a CSIRO Early Research Career (CERC) Postdoctoral Fellowship in Indigenous Health, commenced in April 2023.

The AEHRC and Indigenous Health: Project Reports and Updates

InReach Kids Project Evaluation

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

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

InReach Kids is an integration model developed between Goondir Health Services (GHS; primary health care) and Darling Downs Hospital and Health Service (DDHHS) to provide patient-centric seamless flow of journey for Indigenous patients across two systems, and to streamline services, ensuring less duplication of services, identification of service gaps and improved health outcomes. The InReach intervention focussed particularly on improving health service usage and health outcomes for children, young people, and antenatal, perinatal, and postnatal women.

CSIRO was contracted to conduct a mixed-methods evaluation to assess the appropriateness and effectiveness of the InReach Kids project through process, impact, and outcome evaluations. To date, a final report has been delivered to Goondir Health Services on qualitative evaluation results gathered through health and program staff interviews. Deidentified quantitative data collected by GHS and DDHHS is being finalised for CSIRO to receive and analyse.

Key outcomes from qualitative data showed that the InReach Kids project improved the coordination of care between the two health services; strengthened internal relationships and external partnerships; and led to a sustained increase in staff resourcing. Facilitating factors to project success were also identified, largely revolving around investments in staffing capacity such as dedicated coordinator positions complimented by existing relationships with community. Barriers to project success were largely at the systems level including a lack of data interoperability and short-term funding cycles. Finally, the cultural appropriateness of services was reported upon where hospital staff competency in this area was seen to be improved through partnership with the Aboriginal health service. Findings from the qualitative report will be used by each service to sustain and build upon the current success of the program.

St George Community Wellbeing Centre

Collaborators: Goondir Health Services, Flinders University, Southern Queensland Rural Health, University of Queensland's Centre for Online Health & Rural Medical School, and Indigenous Land and Sea Corporation

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

Goondir Health Service has established the collaborative St George Community Wellbeing Centre (SGCWC) to address health and social needs identified by the local Indigenous community. This Indigenous-led intervention aims to reduce community-wide chronic disease incidence and risk factors by proactively addressing physical, social, emotional, and cultural wellbeing through wrap-around, place-based prevention and community building programs and support services.

The SGCWC activities target all life stages from pre-conception, early childhood, children and young people, new parents, adults and older people. Activities span across health and social emotional wellbeing services, social support, cultural development, youth engagement and empowerment, women empowerment, training and education, exercise and fitness, food security, nutrition and healthy lifestyle interventions and enterprise. The partnership-based approach of the SGCWC was designed in close collaboration with consumers and multiple organisations around the region and draws on the experience and knowledge of these institutions. These partnerships include a range of health, education, training, social services, and counselling and wellbeing service providers.

CSIRO was contracted by Goondir Health Services to co-design the SGCWC Research and Evaluation Framework to generate evidence of the SGCWC model of care chronic disease prevention delivery, effectiveness, cost-effectiveness and scalability. The Research and Evaluation Framework is in final co-design stages following health service and Research Oversight Committee feedback and approvals. Funding for the implementation of the framework has been sought.

The AEHRC and Indigenous Health: Project Updates

Strong-eH: mHealth feasibility study, North Queensland

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

Acknowledgement: We acknowledge and pay respects to the Muluridji (Mareeba region), Gimuy Walaburra Idinji (Cairns region), Turrbal and Yuggera (Brisbane region) Peoples as the Traditional Owners and ongoing custodians of the land and seas on which this learning and research took place.

We partnered with Mulungu and Wuchopperen Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHO) to question if mHealth can improve awareness, understanding and clinical management of hypertension for Aboriginal and Torres Strait Islander people. The Strong-eH mHealth-platform developed at AEHRC integrates a smartphone app and clinic portal. The app allows patients to record clinical measurements while accessing appropriate health promotion materials at a place and time of their choosing. The clinic portal extends healthcare providers surveillance of CVD, allowing at-hand information to initiate therapy and the prioritisation of care.

The Strong-eH study forms part of Andrew Goodman's PhD thesis co-hosted with The University of Queensland, School of Public Health, and CSIROs Australian e-Health Research Centre. The study used a mixed method, co-designed approach engaging with both patients and health service providers to assess the appropriateness, feasibility and effect of the Strong-eH mHealth-platform. Following interviews and focus groups with patients and service providers and a pilot feasibility study, data collection ceased in November 2022. Andrew Goodman submitted his PhD thesis titled: Can an integrated mHealth platform assist in the management of hypertension for Aboriginal and Torres Strait Islander people? to The University of Queensland in April 2023. Critically the Indigenous Health team have committed to feeding back to partner sites of the initial findings of the Strong-eH study to ensure cultural and scientific integrity is maintained.

Strong-eH platform with bluetooth blood pressure readings and clinician portal

Queensland Cardiovascular Research network (QCVRN)

We co-funded and hosted the QCVRN program manager position in the 2022–2023 financial year. QCVRN was launched in 2015 and is the sole entity representing cardiovascular research across the state of QLD. QCVRN comprises members including government, industry and academic stakeholders united in their vision to sustain the network as the established entity representing cardiovascular research across the state of QLD. QCVRN delivers support programs for researchers in areas of professional editing for grants, enabling consumer engagement, facilitating industry partnerships, and providing nationally attended webinars. Collaborative support this year saw the implementation of the inaugural 2022 QCVRN PhD top up scholarship scheme, supporting three PhD candidates an annual $5,000 supplementary award to support their cardiovascular research journey. Prof. Ray Mahoney is a QCVRN steering committee member and Andrew Goodman is the QCVRN program manager (up to April 2023).

eHealth Research Collaboration for Aboriginal & Torres Strait Islander Health

The eHealth Research Collaboration for Aboriginal and Torres Strait Islander Health (the Collaboration) was established in 2019 and is led by Indigenous researchers and scientists who guide the ethos of research activities and responsibilities. The aim of the Collaboration is to promote an evidence base for technology in health care specific to the interests and needs of Aboriginal and Torres Strait Islander people through the facilitation of eHealth research (with respect to consultation, co-design, trial, and evaluation) and the co-development of technologies. The Collaboration membership includes Indigenous and non-Indigenous eHealth engaged stakeholders across Queensland Aboriginal and Islander Health Council (QAIHC), AEHRC, The University of Queensland's Centre for Online Health (COH), and School of Public Health (SPH), the Queensland University of Technology (QUT) Australian Centre for Health Service Innovation (AusHSI), Flinders University and eHealth, Queensland Health.

The collaboration is progressing the work outlined in the Culturally Safe eHealth Interventions With Aboriginal and Torres Strait Islander People: Protocol for a Best Practice Framework published in November. See 'Best Practice Framework – Systematic review' for more. Members of the Collaboration are also working to consider Indigenous data sovereignty in the digital health space.

Best Practice Framework–Systematic review

This project has governance from the eHealth Research Collaboration for Aboriginal and Torres Strait Islander Health. It aims to address a gap in contemporary literature for a best practice guide to the implementation of eHealth with Aboriginal and Torres Strait Islander people. A best practice framework will guide the codesign, implementation and evaluation of eHealth with Aboriginal and Torres Strait Islander people within existing healthcare systems. The initial stage of the research protocol features a systematic review focused on identifying the factors important to Aboriginal and Torres Strait Islander people with e-health adoption and implementation. Progress on this aspect of the protocol is underway with a database searches, successful PROSPERO registration CRD42022380254, screening, data extraction and preliminary thematic coding. Quality analysis of the papers has drawn on both the Aboriginal and Torres Strait Islander Quality Appraisal Tool and the Joanna Briggs Institute Levels of Evidence Effectiveness tool. Publication is expected by early 2024.

Post-doctoral students and PhD Candidates

Andrew Goodman, The University of Queensland/CSIRO into AEHRC Postdoctoral Fellow (April 2023)

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

Postdoctoral fellowship project title: Exploring novel approaches and/or solutions to improve Aboriginal and Torres Strait Islander peoples' cardiovascular health using eHealth.

Andrew's PhD research focussed on the co-design of an mHealth platform specifically tailored for the clinical management of CVD risk factors, in partnership with ATSICCHOs in Far North QLD. Andrew's PhD has been a collaborative project with Wuchopperen Health Service in Cairns and Mulungu Aboriginal Corporation Primary Health Care Service in Mareeba. The PhD project has assessed the appropriateness, feasibility, and effect of utilizing 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. Following the submission of his PhD thesis, Andrew applied for and was successful in securing a Postdoctoral Fellowship role with the AEHRC. The Postdoctoral Fellowship purpose is to lead novel approaches and/or solutions to improve Aboriginal and Torres Strait Islander peoples' cardiovascular health using eHealth.

Melissa Kilburn (APD), James Cook University/CSIRO.

PhD Project title: ADAPTTS: App-based Diet and Physical Activity Tools for the Torres Strait.

Melissa is a clinical dietitian with the Cairns and Hinterland Hospital and Health Service who has previously studied IT. Melissa is undertaking a PhD at James Cook University under the auspices of the Healthy Ageing Research Team (HART), due for completion in 2026. The PhD project involves the development and validation of dietary and physical activity assessment e-tools designed to support primary health care clinicians in delivering chronic disease preventative care in Torres Strait Islander communities of Far North Queensland.

The Health System Analytics group

Group Leader: Dr Rajiv Jayasena

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

The group's research agenda is focussed on supporting and improving health service delivery by applying evidence-driven strategies to support improved health outcomes. 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. The group provides solutions that can help improve and streamline the delivery of care and improve patient outcomes.

The group focuses broadly on three areas of research – artificial intelligence, statistics and operations research to increase productivity and patient safety, evaluation of health service interventions and disease surveillance and response.

The group also has two programs of activity supporting research undertaken at AEHRC, Health Data Engineering and Quality Management System (QMS). These two programs contribute by embedding industrial standards, interoperable software engineering and uplifting the regulatory compliance of AEHRC's software tools and solutions to be scalable-ready for commercialisation or the offering of products for routine use.

Health System Analytics' science and impact highlights for 2022/23

- Successfully delivered a Department of Health and Aged Care supported HOTspots pilot to support integration of the HOTspots surveillance and response program into the Antimicrobial Usage and Resistance in Australia (AURA) program, part of Australia's National AMR Strategy -2020 and beyond.

- Published two Lancet papers: one describing the burden of AMR globally published in Lancet in collaboration with Global Research on AntiMicrobial resistance, GRAM, and another quantifying the burden AMR in Australia published in Lancet Regional Health.

- Comprehensively evaluated the Healthdirect Living with COVID (LwC) program for Healthdirect Australia. The LwC program has supported patient care through efficient triage and by connecting consumers to primary care, enabling early intervention to enhance health outcomes. The LwC program has also contributed to reduced patient flow through GP and hospital doors, saving significant resources and budget.

- Setup of a novel implementation-evaluation approach using co-design methodology to develop an implementation enhancement plan for measuring success of falls prevention workflows in two large hospitals.

- Published a novel approach to predict patient deterioration in the nature journal Scientific Reports. We are also working on trialing an algorithm based on this approach in a Queensland hospital and extending this work to predict deterioration in premature infants with Westmead Neonatal Intensive Care Unit (NICU).

- The team working with the international COVID-19 Critical Care Consortium has published 2 high impact papers including one in the prestigous Critical Care journal. Several others are in the pipeline.

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. We are developing new constructs relevant to virtual care to complement the CFIR 2.0 implementation framework and also developing implementation enhancement plans based on the CFIR/ERIC frameworks.

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

Health Intelligence team

Team Leader: Dr Sankalp Khanna

The Health Intelligence team brings together skills in artificial intelligence, statistics and operations research to further the science behind helping the health system increase productivity and safety through optimising patient, clinician and resource flows and providing intelligent decision support. Working closely with clinicians and health system administrators, we have delivered significant impact in the space of patient flow analytics and are well recognised as leaders in this research space. The team also has a strong track record of developing and implementing precision clinical decision support at point of care for patient management in acute care and primary care settings.

Digital Solutions for Antimicrobial Resistance team

Dr Teresa Wozniak

The Digital Solutions for Antimicrobial Resistance (AMR) team is dedicated to mitigation, preparedness, and response to the threat of AMR. The team has a diverse portfolio of external and CSIRO internal collaborators and is led by experts in the field of public health, system-level and statistical modelling, and social sciences. The team has implemented innovative disease surveillance programs which support efforts in reducing AMR in regional and remote Australia and is working closely with One Health partners to respond to current matters of local and national policy relevant to AMR.

Health Data Engineering team

Team Leader: Derek Ireland

Our Health Data Engineering team is a dedicated team of software engineers who work with scientists across the AEHRC translating our science into solutions for our customers and partners.

Quality team

Senior Quality Manager: Yan Chia

The Quality Team is dedicated to implement a Quality Management System that is compliant with relevant medical devices standards, encompassing ISO 13485, ISO 14971, IEC 62304, IEC 62366 and other applicable standards and regulations. This system will effectively oversee the design and development of Software as a Medical Device within AEHRC.

Health System Analytics: platform technologies and initiatives

Predictive modelling for operational and clinical decision support

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

Since 2007 we have been developing and validating models to predict demand for health services such as ED presentations, inpatient admissions and separations and operating theatres. These models can assist planners and schedulers to improve the delivery of services. For example, daily demand can typically be predicted with over 90 percent accuracy and can be used for staff resourcing, scheduling of elective surgery, identifying when demand is likely to exceed capacity, detecting the start and duration of the annual winter bed crisis, and providing early warning of disease outbreaks.

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

With the increasing implementation of electronic medical records (EMRs) in hospitals, there is growing potential to use the data to inform clinical decision-making in real-time. We have been developing a series of real-time explainable machine learning algorithms for precision decision support at the point of care. These use data captured in electronic medical records and administrative systems to identify patient cohorts of interest for clinical streaming/intervention. Several past and current projects focus on clinical decision support to help reduce hospital readmissions and predict patient deterioration. In 2022–23, we published algorithms developed in partnership with Queensland Health to predict risk of unplanned rehospitalisation and the risk of a patient triggering a clinical deterioration alerting criteria, the Australian Between the Flags (BTF) alert within the next 2, 4, 6 or 8 hours. We are also working closely with the Westmead Neonatal Intensive Care Unit (NICU) to develop models to predict adverse outcomes using clinical and physiological data collected from critically ill preterm newborns.

Syndromic surveillance and aberrance detection to support early detection

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

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

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

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

Digital twins and simulation based operational scenario modelling and optimisation

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

We developed several simulation based scenario models. These typically use discrete event simulations for assessing the flow of patients through the health system. An important step in simulation modelling is to ensure the model captures accurately the flow of patients through a process. The team have demonstrated with multiple 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 2022–23, the team received initial extracts of ambulance, ED, and inpatient data to start building a digital twin of the state-wide patient flow control hub to run what-if scenarios of different operational policies. The digital

twin considers all major hospitals and emergency and elective flows to/from them to form a realistic model of the system. Different scenarios can be tested such as changes in demand, hospital capacity, the proportion of elective surgeries undertaken, patient discharge time, etc. This model will provide a tool to assess the impacts of policies in near real-time. This will provide decision makers with real time situational intelligence to understand current and potential demand impacts on Queensland Health facilities and ensure an optimal system-wide response.

Modernising HOTspots

The HOTspots website is a digital tool that facilitates access for healthcare providers, public health practitioners, and policy makers to up-to-date information on evolving AMR in hospitals and community clinics. This digital tool forms part of a suite of resources provided by the HOTspots Program that aims to support antimicrobial stewardship activities, treatment guideline development and capacity building in regional and remote settings of Northern Australia.

Following an evaluation of an implemented tool (Shiny application), developed by Menzies School of Health Research, HOTspots will provide end-users with a modernised website that will support their data needs to best support clinical and policy decision making.

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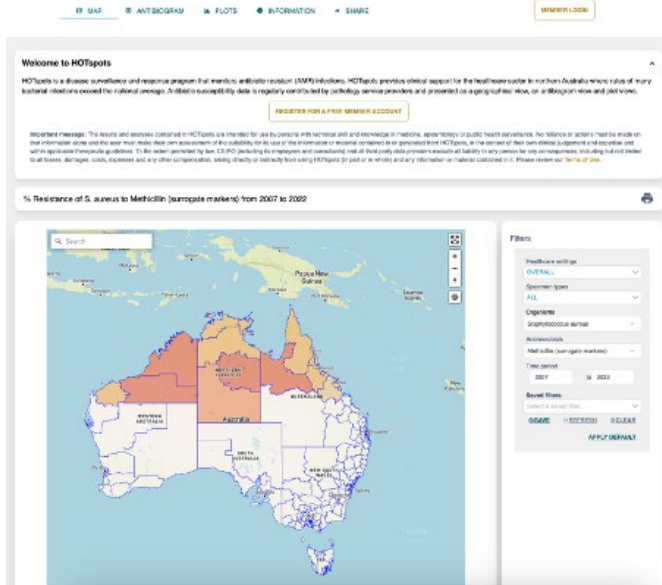
The HOTspots platform

Phenotypic AMR data are collected from pathology service providers by agreement. Data are cleaned and analysed in accordance with international surveillance standards. HOTspots website presents data from clinically relevant bacteria on an interactive map, plots or as a cumulative antibiogram. A new feature is a member's area, that allows users to customise plots and reports to individual needs. The website was implemented as a full-stack web application which is deployed in scalable Docker containers on Google Cloud Platform. Authenticated access, managed by Microsoft Azure, is available for users who may wish to save custom filters and reports for future use. As part of the HOTspots platform, data processing is managed by Python scripts which collate the aggregated AMR data for visualisation on the website.

The new HOTspots website will continue to be used to support stewardship activities in hospitals and community clinics in Northern Australia. Currently HOTspots is available to clinicians through organisational intranet, Northern Territory Primary Health Network and integrated into general practice HealthPathways. The HOTspots Program will continue to build partnerships with local data custodians and end-users to assist in the strategic direction for mitigating the treat of AMR in regional and remote settings of Australia.

The project took 12 months from conception to deployment and is now complete. The website was fully launched in July 2023 and is currently undergoing user acceptance testing (UAT).

Quality Management System (QMS)

AEHRC is implementing a Quality Management System (QMS) to manage the design and development of Software as a Medical device (SaMD) products to ensure CSIRO's ability to deliver outputs to industry needs and expectations.

This initiative will position CSIRO as a differentiated digital health innovation partner by ensuring our products are safe and reliable and research outcomes are justified and reproducible. Transitioning commercially focussed research products under a QMS framework, CSIRO's Digital health innovations will have accelerated translation pathways and hold higher commercial value for CSIRO from our funders, partners, and collaborators.

Implementing QMS across AEHRC will increase the focus on quality and ensure smooth transitions for early-stage R&D to commercially focussed products. This team is working with Group Leaders (change champions) to embark on cross program education and training, documentation generation, software rebuilds and refinement, audits and finally certification to change the program's ways of working to fully embrace quality as a key performance indicator around our science.
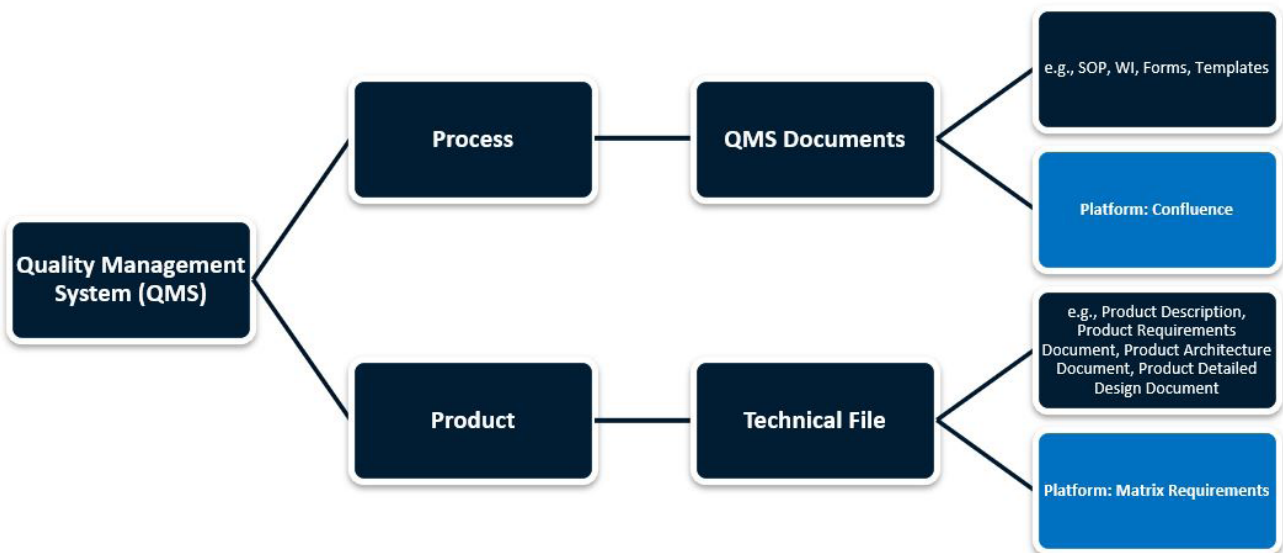
Health System Analytics: project reports

Healthdirect Australia 'Living with COVID' program evaluation

Collaborator: Healthdirect Australia

Healthdirect Australia, a key partner for federal and jurisdiction governments, developed a national approach to connect COVID positive consumers with the right level of care – athe 'Living with COVID (LwC)' program. The model of care aims to assist COVID positive consumers who have a low or medium risk of hospitalisation to self-manage their care at home and/or in consultation with their usual GP. Healthdirect Australia engaged CSIRO to undertake an independent evaluation to determine if the program was achieving its intended aims.

The 'Living with COVID' program consisted of:

- Inbound National Coronavirus Helpline (NCH): 24/7 inbound call centre to assess, triage and provide health advice.
- GP secure messaging system: Notify GP of COVID positive patients.
- Healthdirect Australia website: Support self-managed care at home with digital tools and information.
- NSW Antiviral access pathway.

Our evaluation found that Healthdirect Australia successfully developed and deployed a model of care through the LwC program. The LwC program has supported patient care through efficient triage and by connecting consumers to primary care enabling early intervention to enhance health outcomes. The LwC program has also contributed to reduced patient flow through GP and hospital doors, saving significant resources and budget. The economic evaluation found there were potential cost savings to the health system by triaging patients via the NCH and website and enabling them to self-manage rather than presenting to their GP or hospital ED. The LwC program allows patients to access the right care at the right time and offers the potential to streamline communication, care, and tasks to improve patient outcomes.

A final report was delivered and presented to the Healthdirect Australia board in February of 2023, the findings of which have been presented by Healthdirect Australia at multiple key events and published in media outlets. Selected findings of this evaluation have been submitted for publication, and it is expected that this model of care could be used as a scaffold to address other pressing health concerns of the Australian public.

Outpatient Predictive Appointment Tools (OPAT)

Collaborator: Austin Health in Victoria

Every year there are approximately 3 million new specialist clinic appointments at local hospital networks in Victoria. Demand for these services is growing, driven by an ageing population, increasing burdens of chronic disease and rising community expectations. In 2018, CSIRO obtained funding through the Victorian Government's Public Sector Innovation Fund to collaborate with Austin Health to provide analytics and tools to assist with waitlist management in their outpatient specialist clinics.
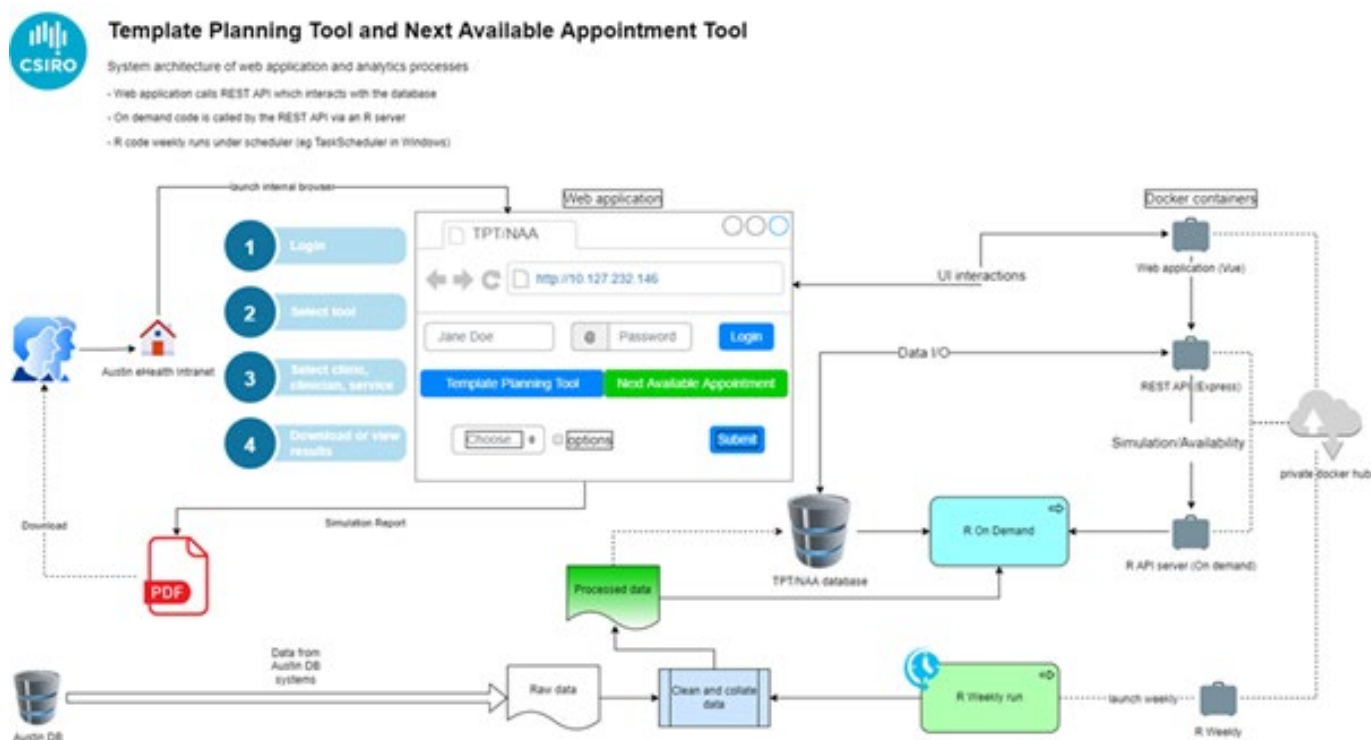
Template planning tool and next available appointment tool.

Two solutions were developed and validated that would assist in the visibility and planning of appointments for outpatient clinics at Austin Health. The Next Available Appointment (NAA) tool was a predictive model that would indicate the next available appointment based on the speciality, clinician and services required. Template Planning Tool (TPT) was developed and validated to optimise the mix of different types of appointments for different specialities in order to minimise the waiting period for patients for appointments.

Both NAA and TPT were then developed as research prototypes in Javascript to operationalise the tools with user interfaces for input selection and output visualisation followed by implementation in the Austin IT environment to undertake a feasibility study.

The three-month long feasibility study showed that whilst clinicians agree the tool is needed, and could be helpful, in its current form as a standalone tool, it is not feasible to integrate it into their daily workflow. Austin Health have since decided that the tool should be embedded into the existing business as usual system and will do this in partnership with Telstra Health. In the longer term, this solution is transferable to other health jurisdictions to manage specialist clinic waitlist demand.

At present CSIRO is in the process of submitting for a provisional patent application for these tools.

Pilot of HOTspots integration into national AMR surveillance system

Collaborator: Australian Government
Department of Health and Aged Care

The HOTspots disease surveillance and response program aims to build resilience to antimicrobial resistance (AMR) and maintain the benefits of effective antibiotics in northern Australia. During 2022–23 we worked closely with the Department of Health and Aged Care to pilot integration of the HOTspots program into the AURA Surveillance System to demonstrate the feasibility and benefit for including antimicrobial resistance (AMR) data from HOTspots to the AURA program. HOTspots remains the only program providing susceptibility data to AURA from all public hospitals in the NT, including community healthcare clinics in the NT and far north WA. HOTspots contribution to AURA ensured inclusion of AMR surveillance data from northern Australia that has historically fallen outside of AMR surveillance reach.

HOTspots is the only implemented and evaluated AMR digital surveillance tool used by clinicians at the point of care. Access to local region-specific susceptibly data is critical for updating guidelines, for stewardship, and the health service's ability to initiate appropriate, timely responses to changing AMR epidemiology. Local and timely data provided at the point of care helps ensure clinicians choose the right drug for the right bug at the right time.

During the pilot period, 214 healthcare services comprised of 164 community health centres and 50 hospitals contributed data from 489,138 susceptibility tests to HOTspots. This data showed geographical differences within northern Australia, and between northern and southern parts of the country, demonstrating the need for ongoing surveillance and response to AMR in this region.

HOTspots impact across northern Australia during the pilot period included:

- contributing to the NTPHN's HealthPathways
- negotiating a signed data sharing agreement with NT Pathology
- providing local evidence for updates of clinical guidelines (i.e. CARPA Standard Treatment Manual)
- supporting capacity building of the regional and rural health workforce
- strengthening stewardship programs in hospitals and community healthcare clinics
- implementing digital solutions that facilitate AMR data use and sharing across sectors and jurisdictions, and
- informing the need for public health action.

ECMOCARD

Collaborators: COVID-19 Critical CRE Consortium incorporating ECMOCARD led by Prof John Fraser

The COVID-19 Critical Care Consortium was established at the start of the pandemic before coronavirus was even named. As of January 2023, the collaboration comprises 441 centres from 63 countries across 6 continents and has collected data from over 26,000 patients admitted to intensive care units.

This study, Extra Corporeal Membrane Oxygenation (ECMO) for 2019 Novel Coronavirus Acute Respiratory Disease (COVID-19 Critical Care Consortium), is a prospective/ retrospective multi-centre observational study of patients in intensive care units with COVID-19. The study's objective is to employ the data being collected from across the world to describe clinical features, the severity of pulmonary dysfunction, ECMO technical characteristics, duration of ECMO, complications, and survival of patients with COVID-19.

We have been working in close collaboration with frontline ICU clinicians across several projects to address specific research questions related to ECMO use on COVID-19 patients. The insights derived from our work are being disseminated via conference presentations as well as high impact peer-reviewed journal publications. Outcomes from this project in 2022–23 include a manuscript published in the high-impact *Critical Care* journal comparing the incidence, demographic profile, management and outcomes of early acute kidney infection in patients undergoing invasive mechanical ventilation for COVID-19-related acute respiratory distress syndrome with a non-COVID-19-related cohort, and another manuscript published in the high impact *Perfusion* journal investigating a rare bleeding complication called iliopsoas haematoma on patients undergoing ECMO support. Several other publications are in the pipeline.

Reach, Change, Maintain

Collaborator: Human Health program, CSIRO Health & Biosecurity

Engagement is key to interventions achieving successful behaviour change and improvements in health. There is scarce evidence in the literature on applying predictive ML models to data from commercially available weight loss programs to predict engagement which could help in supporting participants to achieve their goals. The aim of this study was to develop explainable ML models and exploit their capability to predict the weekly risk of disengagement over 12 weeks on a commercially available, online, weight loss program and explain the output of the developed predictive models. To the best of our knowledge, this is the first study to use ML algorithms to predict weekly disengagement in a web-based, real-world weight loss program.

Findings from this study were published in the prestigious *Journal of Medical Internet Research*. This study showed the potential of applying ML predictive algorithms to help predict and understand participants' disengagement with a web-based weight loss program. There was a considerable improvement in the predictive performance of the algorithms from week 3 of the program. On the basis of the explainability approach employed, the most important features for predicting disengagement in the following week were those related to the total activity on the platform and entering a weight in the previous weeks.

Given the association between engagement and health outcomes, these findings can prove valuable in providing better support to individuals to enhance their engagement and potentially achieve greater weight loss.
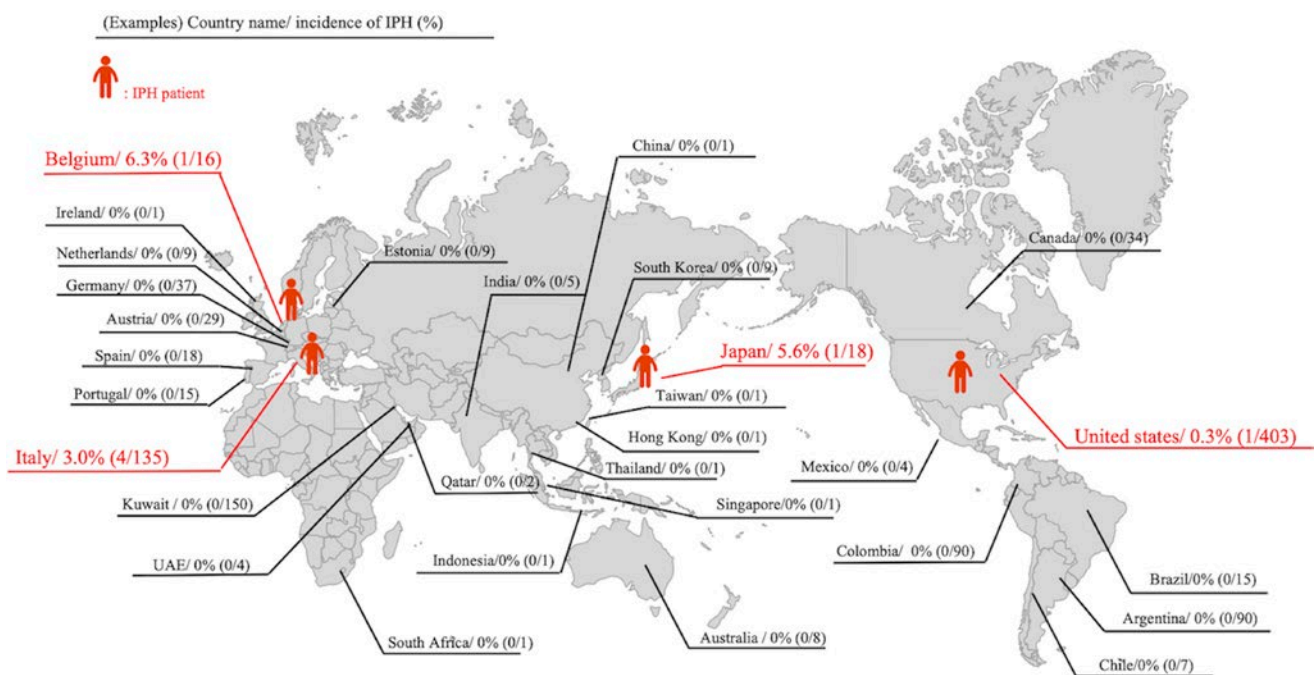
The incidence of iliopsoas haematoma (IPS) during extracorporeal membrane oxygenation in patients with COVID-19. (image source: https://journals.sagepub.com/doi/10.1177/02676591231168285)

Health System Analytics: project updates

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

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

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

The aim of this project is to develop predictive models using high-fidelity physiological signals collected at Westmead NICU to predict adverse outcomes earlier than clinical diagnosis time. In 2022–23, we completed a literature review on pre-processing techniques for premature infant physiological signal data, which is currently under peer review. We presented a paper at the prestigious Medinfo 2023 conference describing the development and validation of an ensemble-based approach for heartrate detection from neonatal ECG data. An algorithm with output correction that ensures reliable and robust detection and prediction of extremely rare events has been proposed. The approach has been successfully applied to bradycardia detection in preterm infants and the results will be soon submitted to high-impact journal. This research has immense translational significance in predicting the likelihood of permanent brain injuries states such as cerebral palsy, severe gut necrosis and physical disabilities.

Syndromic Surveillance for influenza like illnesses and COVID-19 related symptoms

Collaborator: Queensland Health

The team is continuing its investigations into syndromic surveillance and the use of data collected in hospital data systems as a signal to flag outbreaks. Previous efforts have employed techniques based on control charts such as exponentially weighted moving average and cumulative sum charts, and on using the time between events (TBE). More recently, the team has been using concepts adopted from the finance sector and the TBE metric to generate new index measures (a.k.a. variability indices) that capture trends in the underlying data and the use of these to signal outbreaks. A paper describing this work will appear in the proceedings of the prestigious MedInfo 2023 conference. The new methods offer advantages over classical modelling approaches for predicting disease outbreaks. Future research will focus on the continued improvement of these methods and the development of sophisticated surveillance and outbreak detection algorithms based on these methods.

Rauland falls prevention

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

Rauland Australia has developed technology that supports fall 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 fall risk in hospital wards. The system will provide the platform for implementing new workflows on these wards to assist with providing care to high-risk falls patients.

Rauland Australia has commissioned CSIRO to undertake an evaluation of the implementation of their Responder 5 at two hospitals. The team is undertaking a mixed-methods evaluation to understand the effectiveness of the fall prevention workflows delivered in these hospitals on patient and health service outcomes and implementation strategy outcomes. The first round of surveys and interviews were completed at Maitland Hospital, and an implementation enhancement plan was subsequently developed. The implementation enhancement plan actions have since been completed and the second phase of data collection is now in progress. The first data collection phase results have been published and presented at multiple international and national conferences. Northern Hospital has completed the first round of surveys and interviews, and the implementation enhancement plan is currently under development. It will be presented to a co-design workshop later in the year so that action items can be devised and executed in preparation for the follow-up data collection period, expected to occur in mid-2024.

InReach Kids Program Evaluation

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

The InReach Kids Program is an integrated model of care developed between Goondir Health Services and Darling Downs Hospital and Health Service. The program provides a patient-centric care pathway for Indigenous patients across the two health systems by streamlining services, reducing duplication, and identifying service gaps. In doing so, the program will improve health and development outcomes for children and adolescents 0-14 years. The Health Implementation Science team have collaborated with the AEHRC's Indigenous Health team to develop a comprehensive mixed methods evaluation framework that focusses on both process and impact outcomes of the program. The team has also developed a semi-structured interview discussion guide to facilitate the collection of qualitative data to understand the key barriers and enablers of the program's implementation from the perspective of health and program staff. Data collection for the project has finished and a statistical analysis will commence in late 2023 to address the main evaluation outcomes.

AI4M AMR: Estimating current and future risk of AMR

Collaborators: Human Health, Data61 and Environment

This project involves modelling AMR risk, accounting for the differences in healthcare and environment across northern regions of Australia. Data from HOTspots surveillance system is used for this analysis. A spatio-temporal machine learning model is proposed to predict region specific current and future risk of AMR. This highly collaborative project between eHealth, Data61, and Environment BU commenced end of January 2023, and will be completed in June 2025. To date, we have prepared the data, established modelling idea, and constructed an initial AI model. This project has been presented to OneHealth government representatives and other stakeholders for their feedback.

Impact: Region-specific estimates of current and future risks to guide public health professionals and clinicians in their program planning to mitigate risk of AMR.

InReach Kids Program Logic Model

HOTspots surveillance platform
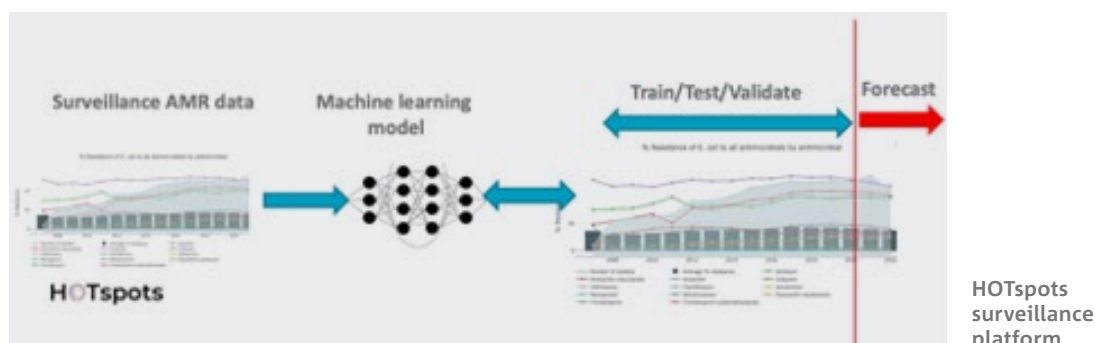
AI-enabled AT Framework for the National Disability Insurance Scheme

Collaborator: The National Disability Insurance Agency

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

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

Collaborator: Molecular Diagnostic Solutions, CSIRO Health & Biosecurity

Carcinoembryonic antigen (CEA) is the current clinically accepted blood-based protein marker to identify colorectal cancer patients who are at risk of an adverse outcome after their initial cancer diagnosis. Using data across two independent studies, in this cross-research-program we identified two avenues for intellectual property (IP) commercialisation pathways. First, we identified a panel of protein biomarkers that perform better than CEA at predicting patient incidence of metastasis or recurrence of cancer within five years. Secondly, we identified a different panel of biomarkers which are used to predict the likelihood of tumour staging upon initial diagnosis. This valuable, interactive clinical decision support tool named 'Dukes' staging prediction tool', is in its early development phase and will be supported via a web-browser. Due to the nature of both IP and commercial strategies for this project, deliverables consist of confidential reports and an online app.

A digital twin of the Queensland Patient Access Coordination Hub (PACH)

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

The Queensland Patient Access Coordination Hub (PACH) is a Queensland Health initiative designed to enhance operational performance and assist with patient flow, utilising real-time intelligence of ambulance and hospital operations across the major South-east Queensland Hospital and Health Services. The team has received funding from the Healthcare Improvement Unit of Queensland Health to develop a digital twin of the PACH unit. This involves developing models to simulate the flow of patients through and across hospitals and capturing processes involving queueing, to optimise organisational objectives such as patient length of stay (LOS) and patient wait times. This will allow for real-time situational intelligence to support scenario planning and informed decision-making to ensure an optimal health system response. We have received ethics approval for the project and the first tranche of historical ambulance, ED and inpatient records required for the development of the digital twin and are engaging in ongoing planning activities with project stakeholders.

Predicting patient deterioration

Collaborator: Queensland Health

The electronic medical record (EMR) provides an opportunity to manage patient care efficiently and accurately. This includes the development of tools that can be used as an aid in clinical decision-making at the bedside for the timely identification of adverse events or acute illnesses preceded by deterioration. In 2022–23, we published a manuscript in the high-impact journal *Scientific Reports* describing the development and validation of a patient risk of deterioration (PRoD) algorithm to predict risk of a patient triggering a clinical deterioration alerting criteria, the Australian Between the Flags (BTF) alert within the next 2-8 hours. In 2022–23 we have commenced planning to extend this algorithm to predict other deterioration criteria, including the Queensland Adult Deterioration Detection System (Q-ADDS). Ethics approvals have been obtained and we are in the process of obtaining site-specific governance approvals. Following algorithm development and validation, we propose to trial the algorithm in a hospital setting. The initial study with Australian Between the Flags (BTF) alert also has been extended to better understand the trustworthiness of the associated explanations.

Patient Risk of Deterioration (PRoD) algorithm pipeline

Insights from Linked Data at WentWest

Collaborators: Western Sydney Primary
Health Network (WentWest)

The Western Sydney Primary Health Network (WentWest) has been partnering over the past many years with trailblazer general practices (GP) in Western Sydney to set up patient centred medical homes (PCMH) to help achieve improved health of populations, enhanced patient experiences, health care cost reductions and better support for health professionals. CSIRO has been working closely with WentWest to analyse outcomes associated with PCMH compared to standard GP care. This first-of-a-kind statistical study draws on linked GP and hospital data collected in the NSW Lumos program to compare associations between care delivered at PCMH vs regular GP practices and patient outcomes such as mortality and hospitalisations to better understand the benefits delivered by the PCMH model. Statistical modelling has been completed and we are currently preparing a manuscript for submission to a high-impact journal for peer review.

Study on Patient Flow in Queensland's public hospitals

Collaborators: Emergency Medicine Foundation, Queensland Health, Queensland Ambulance Service, University of Queensland

In late 2022, CSIRO along with its project partners the University of Queensland, Queensland Health, and the Queensland Ambulance Service commenced a comprehensive project aimed at improving emergency access performance across Queensland's public hospitals. This project is funded via a competitive tender process issued in 2022 by the Emergency Medicine Foundation (EMF) on behalf of Queensland Health with additional in-kind contributions from project partners. The primary objective of the work is to establish an evidence base for factors leading to access block and inform strategies to improve emergency access performance across Queensland's 25 largest public hospitals. The team presented the scope of the study and the proposed modelling at the 2023 EMF Symposium on Improving Patient Flow in Queensland Public Hospitals on Wednesday 8 March 2023 in Brisbane. In June 2023, the team submitted an interim progress report for the project.

Photo: Dr Justin Boyle from the CSIRO Australian e-Health Research Centre, a lead investigator on the study, with Minister for Health and Ambulance Services the Hon Yvette D'Ath at the 2023 EMF Symposium on Improving Patient Flow in Queensland Public Hospitals.

Health System Analytics: postdoc and student highlights

Postdoctoral fellows

Dr Vahid Riahi

During his time as a postdoctoral fellow, Vahid was working on several multidisciplinary projects improving decision-making processes using simulation, optimisation, and machine learning. This included a project for Austin Health in Victoria to improve their appointment booking system, which recently completed the feasibility study stage. In November 2022, Vahid was successful in obtaining a research scientist role within the team. Since then, he is also investigating and developing digital twin-based approaches for operational and clinical decision-making in health.

Dr Jessica Rahman

Jessica's research is focussed on developing explainable machine-learning approaches for clinical decision support. This includes developing algorithms for providing early warning signs of clinical deterioration linked to neonatal mortality and morbidity. She is working on building predictive models using high-fidelity physiological signals using the data. In 2022–23, she conducted a rigorous literature review on physiological signal analysis for neonatal data, which is currently under peer review. She also developed an ensemble technique to reliably detect heartbeats from large-scale premature infant data, which has been accepted for presentation and publication at the prestigious 19th World Congress on Medical and Health Informatics (MEDINFO 2023).

PhD students

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

AEHRC Industry PhD, scholarship University of New South Wales (UNSW). Fraudulent or inappropriate claims from healthcare providers can be costly for government health programs. With increasing numbers of claims, data analysis becomes a bottleneck in the process of detecting abnormal claims. Improving analysis methods could lower the cost of detection as well as increase detection rates. This project will apply machine learning techniques, to whole-of-population Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data sets held by the Department of Health. James submitted his PhD in February 2023 and is waiting on review.

Kristin Edwards, James Cook University

Kristin was a PhD student jointly supervised by James Cook University and CSIRO. Her thesis explored aeromedical patients' journeys in the Central Queensland Hospital and Health Service (CQHHS) region to investigate patient and service outcomes and develop a framework for evaluating service quality. Achieving this aim required linkage between aeromedical data and data from the sending and receiving health facilities, as until now linked data had not previously been available. The overall objective of this study was to explore the performance of a regional aeromedical system to inform the development of a performance evaluation framework for aeromedical services. Kristin submitted her thesis for examination in September 2022 and was awarded her PhD in May 2023.

Vacation students

Christina Lauw, University of Sydney

Christina completed her Vacation student program working in Sydney with Jessica Rahman, a postdoctoral fellow on the team. She developed an interactive and user-friendly Python dashboard for real-time analysis of neonatal vital signs, enabling clinicians to visualize and analyse infant physiological data without needing prior computing knowledge, helping them anticipate patient deterioration. A paper presenting her work has been accepted for presentation and publication at the prestigious 45th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC 2023).

Emma Maddock, Griffith University

Emma was tasked with completing a systematic review of the literature with the Health Implementation Science team to identify barriers and enablers to the provision of virtual health care in primary health settings. The paper has led to conceptualisation of updated implementation frameworks that will have important implications for practice when implementing virtual care solutions. A paper presenting her work has been accepted for presentation and publication at the Evidence Implementation Summit, an international conference to be held in Melbourne, October 2023.

Vacation student projects

Project: Telling science stories: Science communication in digital health

Student: Morgan Gilbert, University of Queensland

Supervisor: Naomi Stekelenburg

How can we tell stories about science? In answering this question, we explored audience engagement, the political landscape of telling stories in an ostensibly agnostic space of science, some of the challenges and opportunities of communicating science from within a large organisation, and the platforms and tools needed to effectively amplify messages.

Project: Identification of emotional dysregulation via wearable sensors

Student: Gabriel Russell, University of Queensland

Supervisor: Moid Sandhu, David Silvera

This project explored machine learning models for the identification of emotional dysregulation using physiological signals from children on the autism spectrum. The physiological signals, such as heart rate and electrodermal activity were collected using wrist-wearable devices. We found that the developed machine learning prediction models were able to detect emotional dysregulation with about 70% accuracy. Later, we implemented the prediction model on an android device to detect emotional dysregulation in real-time and provide alerts to support caregivers with the provision of timely care before any potential meltdown.

Project: Image analysis for optical coherence tomography

Student: Zachary Taylor, Queensland University of Technology

Supervisor: Shaun Frost

This project examined alternative approaches to image analysis for optical coherence tomography angiography (OCT-A). These medical images are collected from the retina in the eye and provide a window into microvasculature health. We developed improved approaches that increased the association between OCT-A markers and measures of cardiovascular health. This could improve our precision health assessment of cardiovascular risk using eye imaging.

Project: Deep learning-enabled automatic breast cancer localisation and segmentation on diffusion weighted imaging

Student: Man Lik Nicholas Wong, University of Queensland

Supervisor: Hang (Hollie) Min, Bowen Xin, Jason Dowling

This project aims to establish a deep learning framework for breast cancer segmentation on diffusion-weighted MRI (DWI). A single-stage approach using nnU-Net achieved a mean intersection over union (IOU) of 0.31, while a two-stage approach using nnDetection network and nnU-Net achieved a mean IOU of 0.33.

Project: Radiology textual prompt-to-chest X-ray synthesis using latent diffusion models (AN)

Student: Jenna Supper, University of Queensland

Supervisor: Aaron Nicolson, Jason Dowling, and Bevan Koopman

Jenna developed initial methods for generating chest X-rays from textual prompts using latent diffusion models. Her work will lead to methods of generating diverse synthetic chest X-ray datasets for tasks such as creating digital twins. Her work is now being used as the foundation for new medical image synthesis methods.

Project: Applying a deep-learning-based model for medical image registration in cerebral palsy

Student: Hannah Tay, Monash University

Supervisor: Ashley Gillman, Alex Pagnozzi, Febrio Lunardo

Hannah explored established deep learning methods for aligning brain MRIs, and their application in cerebral palsy analysis. Even with a limited training dataset, deep learning was able to match or outperform traditional methods and run faster in healthy brains. We learned that the performance did not generalise to brains of cerebral palsy sufferers: these datasets require specialised training.

Project: Intelligent analysis and interactive visualisation for mobile health data

Student: Milan Joseph Thomas, University of New South Wales

Supervisor: Jane Li, Kaley Butten, Jessica Rahman
This project explored the use of machine learning techniques (e.g., RNN) to analyse timestamped mHealth sensor and health measurement data. The blood glucose levels collected from the MoTHer platform were used to train and test LSTM and GRU based models for time series forecasting and an interactive clinician alert system based on customized thresholds.

Project: Barriers and enablers to implementation of virtual care in Australian primary health care systems: A systematic, scoping review

Student: Emma Maddock

Supervisor: Alana Delaforce, Norm Good, Joy Parkinson

It remains unclear what the key influences are to the uptake of virtual models of care within Australian primary health care systems. This systematic review used the Consolidated Framework for Implementation Research (CFIR) and Theoretical Domains Framework (TDF) to uncover the key barriers and enablers to implementing virtual care models. The use of frameworks makes the findings more generalisable and will be important for informing future implementation efforts in this setting.

Project: Detecting depression-related movement changes in older adults using smart home motion sensors – a feasibility study

Student: Mitchell Dennis, James Cook University

Supervisor: Deepa Prabhu, David Silvera

This project explored the feasibility of using motion sensor data to track changes in daytime movement patterns within the home, and their potential association with depression in older adults. The study analysed the motion sensor data collected during a one-year smart home trial (DACS Study) and explored their association with Geriatric Depression Scale (GDS) scores collected at three different time points during (i.e., baseline, mid-trial, and end-trial). Results showed that movement patterns are generally reduced when older adults are in a depressed state compared to when being in a not-depressed state. In particular, the reduced movement activity in depressed states was significant when the participant's GDS state changed between depressed and not depressed.
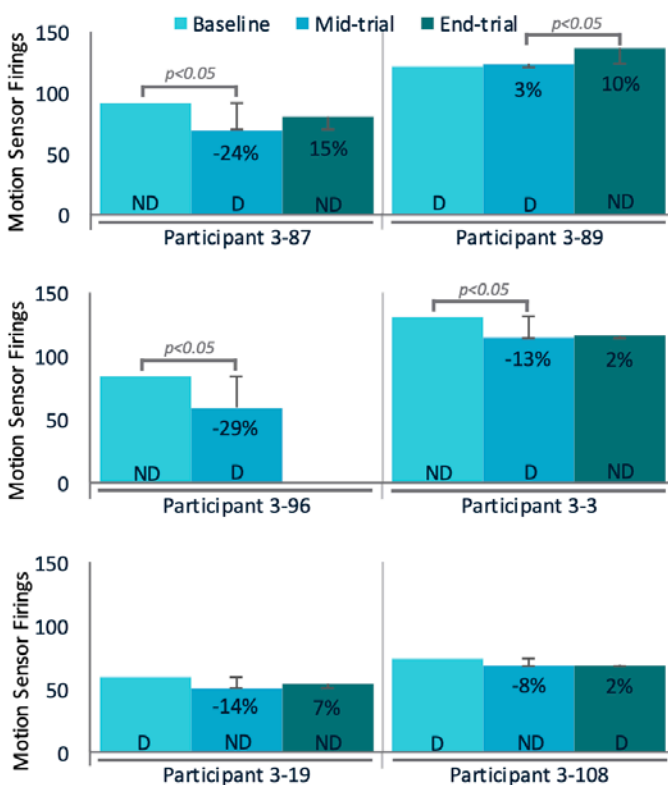
Average motion sensor firings at baseline, mid-trial, and end-trial in participants whose depression states changed between depressed (D) and not depressed (ND) during the trial

Project: Towards osteomyelitis management – development of a bone detection system in diabetic foot X-rays using deep learning techniques

Student: Evan Diamandikos

Supervisor: Maryam Mehdizadeh, Janardhan Vignarajan

This project used a machine-learning algorithm as a method for training and predicting bone locations in diabetic foot X-rays and was able to confidently predict bone placements of larger bones in the foot. This is tested with the intent of quickly and automatically identifying amputations and anomalies in the foot.

Project: Developing new cognitive marker to test cognitive decline for clinical trial drug testing

Student: Matthew Lee

Supervisor: Rosita Shishegar, James Doecke

This project enhances the detection of cognitive decline in Alzheimer's disease using machine learning-optimised cognitive composite scores. It compares the commonly used composite score, preclinical Alzheimer cognitive composite (PACC), against machine learning-optimised composite scores.

The results showed that composite score computed using PCA provides a practical solution to detect cognitive decline with improved performance in tracking cognitive decline in mild cognitively impaired progresses compared to PACC score.

Project: Detecting and visualising synergistic protein networks associated with drug sensitivity and resistance in a pan-cancer cohort

Student: Lujain Elazab

Supervisor: Priya Ramarao-Milne, Roc Reguant

This project used a novel machine learning method to identify higher-order synergies between proteins in cancer cell line drug sensitivity data. The results identified novel proteomic markers that correlate with drug sensitivity and resistance, including proteomic signatures that predict drug response to drug classes such as microtubule inhibitors and kinase inhibitors.

Project: eHealth Best Practice with Aboriginal and Torres Strait Islander people – what does the literature say?

Student: Charankarthi Musuwadi, University of Queensland

Supervisor: Georgina Chelberg

Evidence is growing rapidly for the adoption and effectiveness of e-Health interventions with Aboriginal and Torres Strait Islander people. This project contributed to the development of a best practice framework through a systematic literature review that identified important factors in culturally safe e-Health interventions with Aboriginal and Torres Strait Islander people.

Project: Development of an Interactive Dashboard to Analyse Physiological Signals in the Neonatal Intensive Care Unit

Student: Christina Lauw, University of Sydney

Supervisor: Dr Jessica Rahman, Dr Aida Brankovic, Dr Sankalp Khanna

Premature babies and those born with a medical condition are cared for within the neonatal intensive care unit (NICU) in hospitals. Monitoring physiological signals and subsequent analysis and interpretation can reveal acute and chronic conditions for these neonates. Several advanced algorithms using physiological signals have been built into existing monitoring systems to allow clinicians to analyse signals in real time and anticipate patient deterioration. However, limited enhancements have been made to interactively visualise and adapt them to neonatal monitoring systems. To bridge this, in this paper we describe the development of a user-friendly and interactive dashboard for neonatal vital signs analysis written in the Python programming language. The analysis can be performed without prior computing knowledge.

NHMRC, MRFF and ARC grants

Scientists at AEHRC are chief and associate investigators on many grants from Australia's foremost medical research grant bodies, including the National Health and Medical Research Council, the Medical Research Future Fund, and the Australian Research Council.

Current grants are listed below. Updates on the projects are provided in each group's section.

National Health and Medical Research Council (NHMRC)

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

Years funded: 2016–2023

Chief Investigator: Professor Michael Breakspear

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

This study examines the interplay between genetic, epigenetic and environmental factors for dementia. We are working to identify risk factors that could be modified through intervention, such as lifestyle changes.hbb

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

Years funded: 2019–2023

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 in 300 infants with cerebral palsy or at high risk of cerebral palsy will evaluate the effects of 'GAME' (Goals Activity Motor Enrichment, an early training intervention) versus traditional passive early intervention on gross and fine motor skills at two years of age. We will also evaluate the secondary outcomes of neuroplasticity on MRI, cognitive skills and quality of life.

NHMRC Centre for Research Excellence in Digital Health

Years funded: 2018–2023

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

Years funded: 2019–2024

Chief Investigator: Roslyn Boyd

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

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

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

Years funded: 2022–2023

Chief Investigator: Associate Professor Alicia Spittle, University of Melbourne

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

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

NHMRC Dementia Research ADNET

Years funded: 2018–2023

Chief Investigator: Professor Chris Rowe

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

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

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

Years funded: 2019–2022

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

AEHRC Investigators/Chief Investigator E: Dr Vincent Dore

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

NHMRC Boosting Dementia Research Grants
Holistic approach in primary care for preventing memory impairment and dementia (HAPPI MIND)

Years funded: 2019–2024

Chief Investigator: Dr Johnson George, Monash University, Melbourne

AEHRC Investigators: Dr Rajiv Jayasena, Dr Marlien Varnfield

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

NHMRC/JPND Project Grant
Early detection of Alzheimer's disease subtypes (E-DADS)

Years funded: 2020–2023

AEHRC Investigators/Chief Investigator A for NHMRC: Dr Pierrick Bourgeat

Collaboration Lead for JPND: Professor Daniel C Alexander, UCL

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

NHMRC PROTECTMe
Assessing antenatal maternal melatonin supplementation in foetal growth restriction to improve neurodevelopmental outcomes

Years funded: 2020–2024

Chief Investigator: Dr Kirsten Palmer, Monash University

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

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

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

Years funded: 2020–2025

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 Australian Genomics Health Alliance

Years funded: 2016–2023

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

AEHRC Investigators: Dr David Hansen, Dr Denis Bauer

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

NHMRC-EU Collaborative Research Grants
Clinical validation of artificial intelligence for providing a personalised motor clinical profile assessment and rehabilitation of upper limb in children with unilateral cerebral palsy

Years funded: 2022–2027

Chief Investigator: Professor Roslyn Boyd, University of Queensland

AEHRC Investigators: Dr Alex Pagnozzi, Dr Jurgen Fripp

The broad aim of the AINCP program is to identify, collect and combine multiple clinical and digital biomarkers (clinical multiaxial assessments, brain structure and function, upper limb daily movement) to stratify distinct functional subgroups in children with unilateral cerebral palsy (UCP), and create the first diagnostic decision support tool (dDST). This will inform the decision-making process for providing an accurate prognosis and individualised rehabilitation.

NHMRC Synergy Grant
Cerebral palsy SYNERGY network to protect, repair and improve outcomes

Years funded: 2022–2027

Chief Investigator: Professor Roslyn Boyd, University of Queensland

AEHRC Investigators: Dr Jurgen Fripp

Cerebral palsy (CP) is a life-long disability with immense burden (0.14% GDP, $1.47b p.a.). The incidence of CP has reduced by 30% to 1 in 700 children as a result of international multidisciplinary research on prevention, neuroprotection and improved maternal and neonatal care. Our diverse CP Synergy Network will accelerate this reduction in the rate and severity of CP by developing novel early biomarkers (neuroimaging, EEG, genomics, liquid biopsy) to improve fetal and neonatal diagnosis, prognosis, prediction to inform precision medicine clinical trials of neuroprotectants (melatonin, cell therapies) and intensive neurorehabilitation to improve motor, cognitive, psychological and health outcomes for children with CP and their families. Our main aim is to prevent CP and/or

ameliorate the early brain injury by developing and testing new interventions then translate effective interventions rapidly into clinical practice. We have engaged consumers at every step in the research process to ensure relevance to persons with CP. Involvement of the Australian CP Register will enable testing of longer-term network outcomes at 5 years of age. Our translation objective is to ensure effective treatments are implemented earlier into clinical practice by determining costs, consequences, and effectiveness to inform the NDIS.

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

Years funded: 2021–2026

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

AEHRC Investigator: Dr Pierrick Bourgeat

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

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

Years funded: 2021–2023

Chief Investigator: Professor Ian Alexander, University of Sydney

AEHRC Investigator: A/Prof Denis Bauer

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

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

Medical Research Future Fund (MRFF)

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

Years Funded: 2020–2024

Chief Investigators: Professor Ralph Martins, Macquarie University

AEHRC Investigators/Chief Investigator G: Dr Jurgen Fripp

Identifying and implementing strategies to optimise the cognitive health and wellbeing of older Australians is crucial to 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 proposal to validate the efficacy of a multidomain treatment plan that may benefit cognitive and brain health in Australia.

MRFF Future Frontier Stage 1
New frontiers in personalised prevention of CAD

Years funded: 2021–2022

Chief Investigators: Professor Gemma Figtree, University of Sydney

AEHRC Investigators: Dr Denis Bauer, Dr Natalie Twine

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

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

Years funded: 2021–2022

Chief Investigators: Professor Jonathan R Iredell, University of Sydney

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

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

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

Years Funded: 2021–2025

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

AEHRC Investigators: Dr Denis Bauer, Dr Natalie Twine

The project will develop and evaluate a national program for automated, systematic reanalysis of genomic data to deliver improved diagnostic outcomes in large cohorts of rare disease patients. They will harness continuously updated knowledge bases of disease-associated 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% salary for a postdoc within the Genome Insights team for 3 years.

MRFF Targeting treatable traits in COPD to prevent hospitalisations (TERRACOTTA)

Years Funded: 2021–2024

Chief Investigators: Dr Johnson George Monash University

AEHRC Investigators: Dr Rajiv Jayasena

This project aims to evaluate the efficacy of a practice nurse-coordinated intervention – Targeting Treatable Traits in COPD to Prevent Hospitalisations (TERRACOTTA) in the Australian primary care. The specific objectives are to:

a. test the efficacy of the interdisciplinary intervention at improving QoL;

b. test the efficacy of the interdisciplinary intervention at preventing hospital/ED visits;

c. optimise the diagnosis and management of obstructive airway diseases in primary care; and

d. improve self-management using action plans and mobile health support.

MRFF Clinical Trials Activity 2019 Rare cancers, rare diseases and unmet need ataxia-telangiectasia: treating mitochondrial dysfunction with a novel form of anaplerosis

Years funded: 2020–2023

Chief Investigator: Professor David Coman, University of Queensland

AEHRC Investigators: Dr Jason Dowling

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

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

Years funded: 2022–2026

Chief Investigator: Professor Roslyn Boyd, University of Queensland

AEHRC Investigators: Dr Kerstin Pannek

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

MRFF Dementia, ageing and aged care mission blood testing to predict and discriminate dementias

Years funded: 2021–2026

Chief Investigator: Professor Ashley Bush, University of Melbourne

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

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

MRFF Digital infrastructure for improving First Nations' maternal and children's health

Years funded: 2022–2026

Chief Investigator: Professor Clair Sullivan, University of Queensland

AEHRC Investigators: Dr Michael Lawley

The DIFFERENCE project will deliver the largest connected First Nations data infrastructure to ensure the best possible start to life for First Nations Australians. Building on strong partnerships prioritising First Nations data sovereignty and governance, it will develop a data linkage platform with a nationally agreed health data set for First Nations child and maternal health outcomes, and interoperability standards – all with one aim – to support closing the gap in maternal and perinatal health disparities between First Nations and non-First Nations mums and infants. This project will also generate sophisticated machine learning analytics to foster iterative quality improvement and will adopt international standards to support scalability.

MRFF NEWBORN GEN SEQ TRIAL: NEWBORN GENomicSEQuencing in screening: Therapy ready and information for life

Years funded: 2022–2026

Chief Investigator: Professor Bruce Bennetts, University of Sydney

AEHRC Investigators: Dr Denis Bauer, Dr Natalie Twine

Newborn screening (NBS) enables early diagnosis and management of serious health conditions leading to better health outcomes and the number of diseases that would benefit from the inclusion in NBS continues to grow. This trial will demonstrate the use of next generation sequencing as a universal platform for genomic testing in NBS, and ultimately will ensure individuals with genetic disorders can benefit from rapid diagnosis and access to life-changing novel therapies.

Australian Research Council

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

Years funded: 2020–2022

Chief Investigator: Luping Zhou, University of Sydney

AEHRC Investigators: Dr Jurgen Fripp, Dr Pierrick Bourgeat

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

ARC
Training centre for next-gen technologies in biomedical analysis

Years funded: 2022–2026

Chief Investigator: Prof Killugudi Swaminatha Iyer, Western Australia University

AEHRC Investigators: Dr Denis Bauer

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

AEHRC Publications 2022–2023

Journal Publications

1. A. Nicolson, K. Paliwal, S. Roy, 'On supervised lPC estimation training targets for augmented kalman filter-based speech enhancement', *Speech Communication*, pp. 49-60, Jul 2022.

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4. A. Delaforce, J. Li, M. Grujovski, J. Parkinson, P. Richards, M. Fahy, N. Good, R. Jayasena, 'Creating an implementation enhancement plan for a digital patient fall prevention platform using the CFIR-ERIC approach: A qualitative study', *International Journal of Environmental Research and Public Health*, vol. 0, pp. 17, Feb 2023.

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12. A. Bell, J. Boyle, Y. Xie, S. Khanna, N. Good, D. Rolls, M. Romeo, 'Mortality and readmission differences associated with after-hours hospital care: a population-based cohort study in Queensland Australia', *Health Science Reports*, pp. e1150, Mar 2023.

13. A. Wickramarachchi, Y. Lin, 'Binning long reads in metagenomics datasets using composition and coverage information', *BMC Algorithms for Molecular Biology*, pp. 15p, Jul 2022.

14. B. McNicholas, E. Rezoagli, A. Simpkin, S. Khanna, J. Suen, P. Yeung, D. Brodie, G. Li Bassi, T. Pham, G. Bellani, J. Fraser, J. Laffey, 'Epidemiology and outcomes of early-onset AKI in COVID-19-related ARDS in comparison with non-COVID-19-related ARDS: insights from two prospective global cohort studies', *Critical Care*, pp. 14, Jan 2023.

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