THE AUSTRALIAN

E-HEALTH

RESEARCH CENTRE

LEADING THE WAY IN HEALTH IT RESEARCH

ANNUAL REPORT 2018/2019

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THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

AN UNINCORPORATED JOINT VENTURE BETWEEN CSIRO AND THE QUEENSLAND GOVERNMENT, THE AUSTRALIAN E-HEALTH RESEARCH CENTRE (AEHRC) IS THE LEADING NATIONAL DIGITAL HEALTH RESEARCH FACILITY APPLYING INFORMATION AND COMMUNICATION TECHNOLOGY TO IMPROVE HEALTH SERVICE DELIVERY FOR AUSTRALIANS.

Established in 2003 with initial funding from the Department of State Development and CSIRO, the partnership was extended in 2007 for a further five years with funding from CSIRO, Queensland Health and the Department of Employment, Economic Development and Innovation.

The partnership was extended again in 2012 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 again in 2017 for a further five years.

As CSIRO's e-Health Research Program – part of CSIRO Health and Biosecurity – the Australian e-Health Research Centre has grown to a national research centre. In 2009, the AEHRC established the Australian Tele-health Research and Development Group (ATRDG) in Perth in conjunction with the Western Australian Department of Health. While the initial focus of this activity was on telemedicine and ocular imaging technologies the group has grown to include telemedicine delivery for a wide range of conditions. Through further CSIRO in-kind contributions and other external funding the AEHRC also has scientists and engineers in Sydney and Melbourne.

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, and
- increase the pool of world-class e-health expertise in Australia.

The AEHRC's multidisciplinary team conducts research across health informatics, biomedical informatics, and health services, and includes internationally prominent researchers, software engineers and doctoral students, dedicated to serving the needs of patients, clinicians and health service providers.

FOREWORD BY CHAIRMAN AND CEO

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE HAS AGAIN HAD AN EXCELLENT 12 MONTHS DELIVERING E-HEALTH IMPACTS AND SCIENTIFIC EXCELLENCE TO OUR UNINCORPORATED JOINT VENTURE PARTNERS, CSIRO AND QUEENSLAND HEALTH, AND TO OUR RESEARCH COLLABORATORS AND CUSTOMERS AROUND AUSTRALIA.

The past year has seen more implementation of AEHRC technologies by our health service partners around Australia, along with the growing impact of AEHRC technologies internationally. This delivery demonstrates the value of our work, with our health service partners such as Queensland Health benefiting from the science and innovation that CSIRO brings, and CSIRO benefiting from the deep collaborations with clinician and health services executives.

The AEHRC is well positioned to capitalise on a number of trends in healthcare. A significant trend is the increased interest in the use of artificial intelligence to improve all parts of the health system; our research uses many different types of AI techniques across our program. We are a founding member of the Australian Alliance for Artificial Intelligence in Healthcare, a new initiative led by Macquarie University with over 60 partners. The AEHRC is also involved in CSIRO initiatives in AI through the new Artificial Intelligence and Machine Learning Future Science Platform.

A second trend is the increase of data interoperability in healthcare, driven by the new Fast Healthcare Interoperable Resources (FHIR) standard from HL7. The AEHRC was an earlier adopter of FHIR, and our expertise is now helping drive many parts of our research. We have also partnered with the University of Queensland to introduce a Health Informatics on FHIR course for third-year IT students.

We have continued to grow our engagement and delivery around Australia, with our teams in Brisbane, Sydney, Melbourne and Perth all growing over the past 12 months. Our research groups and teams are national and work together to deliver to our health service and research collaborators around Australia.

To recognise and prepare for further growth we have introduced two new groups this year: Health System Analytics, and Transformational Bioinformatics. Along with our existing Health Informatics, Health Services and Biomedical Informatics groups and our Australian Tele-health Research and Development group in Perth, we are well placed for further growth.

OUR WORK WITH QUEENSLAND HEALTH HAS CONTINUED TO GROW.

This year saw eHealth Queensland implement a Queensland Clinical Terminology Service (QCTS) using AEHRC technology. The QCTS will connect to the National Clinical Terminology Service and provide standardised code systems and terminology for all Queensland Health clinical information systems. This is just one of many projects where our health informatics and health system analytics research teams are working with Queensland Health.

The AEHRC is also part of the Queensland Genomics Health Alliance and the Jamieson Trauma Institute – new initiatives from Queensland Health. Our links with clinical research remain strong, with our scientists as key collaborators in areas such as cerebral palsy and Alzheimer's disease, and our Mobile Health and Health Internet of Things teams continue to lead multiple trials with Queensland partners.

Our Perth group, the Australian Tele-Health Research and Development Group, continues to work with the Western Australian Department of Health. Recently an implementation of our Medical Image Communication and Exchange (MICE) platform went live at Fiona Stanley Hospital, supporting the capture and exchange of images of wounds and burns to support clinical care. We have also broadened our work with WA Health with a data analytics project, to identify opportunities to improve theatre scheduling and forecast demand at country hospitals.

The AEHRC continues to deliver to a large number of Victorian partners, including the Florey Institute, the Murdoch Children's Research Institute, and the Walter and Eliza Hall Institute of Medical Research. We have also been working with the Victorian Agency for Health Information (VAHI) to improve hospital reporting, and with the Department of Health to evaluate the effectiveness of the HealthLinks trial.

WE HAVE ESTABLISHED NEW COLLABORATIONS IN NEW SOUTH WALES.

Our Bioinformatics group is now working with the Children's Medical Research Institute at Westmead, and our patient risk stratification algorithms have been trialled at Murrumbidgee hospital as part of the eHealth NSW Innovation program.

Nationally the AEHRC continues to contribute and lead large collaborations. We now lead a large project with the CRC for Northern Australia to develop and trial referral pathways for remote ophthalmology services, including to Indigenous communities.

We also continue to contribute to genomics health alliances, with AEHRC technology now powering collection of deep phenotype data for Australian Genomics Health Alliance clinical projects.

Our Biomedical Imaging team continues to partner around Australia, contributing to the new NHMRC Alzheimer's Disease Network (ADNeT), and partnering in projects for cerebral palsy and prostate cancer treatment among others.

In addition to our ongoing collaboration with the Australian Digital Health Agency in the National Clinical Terminology Service, the AEHRC has this year delivered a large project for the Department of Health. The GP Data Quality Foundations project established standards for the direct sharing of patient records between GPs.

This year we also grew our Indigenous Health research with the addition of a Senior Research Scientist in Indigenous Health. Over the past 12 months we have seeded a number of projects with Indigenous communities around Queensland, from Brisbane to Aurukun in Far North Queensland.

The AEHRC is now an established part of Australia's digital health ecosystem, contributing to the digital health and clinical research ecosystem. Going into the new financial year, we are well placed to continue to implement our 2017-2022 strategy and continue the growth of the past five years.

Richard Royle

Chair
AEHRC

David Hansen

Chief Executive Officer
AEHRC

BOARD OF DIRECTORS

RICHARD ROYLE

Chair, the Australian e-Health Research Centre

Richard is a partner at PwC and is the national and regional digital health lead. He has over 30 years of senior executive experience in the public, for profit and not for profit private hospital sectors in Australia. Richard is a 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.

BRUCE LINAKER

Bruce Linaker is the Acting Chief Executive for eHealth Queensland and Acting Chief Information Officer for Queensland Health and is responsible for advancing healthcare through digital innovation.

Bruce is a seasoned executive with a strong ICT delivery and business transformation background in a variety of industries and countries. As the Chief Executive of eHealth Queensland, Bruce is responsible for in excess of 1,600 staff and delivery of over $1 billion worth of ICT-enabling projects. Before joining eHealth Queensland in December 2016, Bruce was the Regional Head, Portfolio Management Asia Pacific for the global French/ Swiss company LafargeHolcim and was based out of Manila, Philippines. Bruce established the portfolio management team responsible for project delivery and implemented demand and resource management processes servicing up to 10 countries with a 45,000 user-base. Prior to this he held General Manager Professional Services roles with Fujitsu and DWS, along with senior and executive roles with the Department of Main Roads, QSuper, CUA, Suncorp, NSW Health and Aurizon.

Bruce is a values-based leader and is passionate about helping to enable patient-centric care through successful delivery of digital technology. Bruce is a recent graduate of the Australian Institute of Company Directors.

PROFESSOR KEITH MCNEIL

Professor Keith McNeil plays a key role in the clinical leadership of the statewide eHealth program. He works closely with key stakeholders to maximise the clinical and patient safety benefits associated with technology in the healthcare setting, while minimising risk.

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

More recently, Prof McNeil was Chief Clinical Information Officer, National Health Service, United Kingdom following roles as Chief Executive Officer at Addenbrooke's Hospital and Cambridge University Hospital Foundation Trust.

BOARD OF DIRECTORS (CONTINUED)

ROB GRENFELL

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

Rob has broad-ranging public health experience including:

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

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

ADRIAN TURNER

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

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

DR RICHARD ASHBY AM

From: January 2009 to January 2019

Dr Ashby is the Chief Executive of eHealth Queensland responsible for advancing healthcare through digital innovation.

In 2016 Dr Ashby oversaw the successful delivery of Australia's first large-scale digital hospital, the Princess Alexandra Hospital, as the Chief Executive of Metro South Hospital and Health Service. Dr Ashby believes that digital healthcare is one of the most important revolutions in healthcare – providing highly connected and interactive models of care that support personalised, precise and well-informed treatment of patients across care settings and care teams.

Dr Ashby is regarded as one of the state's most experienced clinicians and health administrators. In 2010, Dr Ashby was awarded a Member of the General Division of the Order of Australia for service to emergency medicine, medical administration, and a range of professional associations. He is active across a broad range of areas, including teaching, research and consultancy.

Dr Ashby contributes to a significant number of organisations/committees. His roles include:

- Chairman, Queensland Policy and Advisory Committee on Health Technology
- Chairman, eHealth Executive Committee
- Senior Responsible Owner, Queensland Digital Hospitals Program
- Board Member, Australian e-Health Research Centre
- Council Member, Queensland University of Technology Council.

CATHY FORD

From: 2015 to Feb 2019

Cathy Ford has been acting in the position of Chief Information Officer of the Metro North Hospital and Health Service since December 2017. Cathy's emphasis during this time has been on preparing the foundations for the digital transformation of the health service through targeted planning and investment activities.

Cathy's substantive role is the Chief Digital Officer of eHealth Queensland. In this role Cathy was responsible for the development of both the digital health and innovation strategies as well as the investment roadmap and associated oversight activities.

As a management & ICT professional Cathy's focus is to work with organisations to transform their business by developing strategies to make better use of people, information, systems & technology.

With over 25 years in the industry she has worked with many executives and their teams on transformation activities that delivered sustained change.

Cathy graduated from the University of Queensland with first class honours, holds a graduate diploma in IT and is a graduate of the Australian Institute of Company Directors.

RICHARD SYMONDS

Minutes Secretary

KELLY TIGHE

Finance Manager, CSIRO

MEETINGS

Board Meetings for 2018/2019 were held as follows:

- 27th August 2018
- 19th November 2018
- 18th March 2019
- 4th July 2019

RESEARCH AND INVESTMENT ADVISORY COMMITTEE

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

Chair

- **Prof Keith McNeil**, Chief Clinical Information Officer, Queensland Health

Members

- **Dr Andrew Staib**, Metro South Health and Hospital Service, and e-Health Queensland
- **Mr David Bunker**, Executive Director, Queensland Genomics Health Alliance
- **Dr David Hansen**, CEO, Australian e-Health Research Centre
- **Dr James Lind**, Director, Emergency Medicine Training, Gold Coast Hospital Emergency Department
- **Dr Michael Steyn**, Director Anaesthetics & Perioperative Medicine, Royal Brisbane & Women's Hospital
- **Dr Claire Sullivan**, Chief Digital Health Officer, Metro North Hospital and Health Service
- **Ms Kate Galbraith**, Manager, Digital Strategic Partnership, eHealth Queensland
- **Dr Michael Draheim**, Chief Information Officer, Metro South Health and Hospital Service
- **Ms Tanya Harch**, Director, Strategic Partnerships, Office of the Chief Executive, eHealth Queensland

A number of AEHRC staff members attended RIAC meetings during 2018-2019 as guest presenters.

10 September 2018

At this meeting the RIAC delved deeply into the research of the AERHC Health Services Group, with a number of presentations from scientists and engineers.

- AEHRC CEO Update – **David Hansen**
- Health Services research – **Mohan Karunanithi**
- Chatbots in health – **David Ireland**
- Mobile Health research – **Marlien Varnfield**
- Health Internet of Things – **Qing Zhang**
- CRC for Northern Australia – **Justin Boyle**

ANNUAL E-HEALTH RESEARCH COLLOQUIUM

Over 300 people attended this year's 15th Annual e-Health Research Colloquium, hosted by the Australian e-Health Research Centre at the RBWH Education Centre in Brisbane on 26 March 2019.

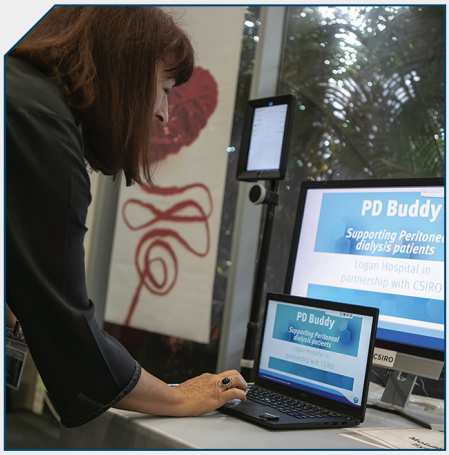
The digital health innovations we are striving to deliver around the world are not for the sake of moving technology forward – they're for the advancement of healthcare.

That was one of the key takeaways from the Australian e-Health Research Centre's 15th annual e-Health Colloquium in Brisbane, which gathered together leaders in digital health from around the world.

With a world-class line-up including leaders from NHS England, HL7's FHIR, the Australian Digital Health Agency and more, the day's discussions showed that while we have room to grow, we are moving in the right direction in Australian healthcare.

HAVING THE DATA ISN'T ENOUGH, WE NEED TO USE IT. INTEROPERABILITY IS KEY.

With the digital revolution we have seen a massive increase in data generation and collection across industries, particularly in healthcare.



This brings its own challenges around efficient data collection and management, but popping up in discussions throughout the Colloquium was the point that just having the data isn't enough; we need to be using it properly.

According to Keith McNeil, Assistant Deputy Director and Chief Clinical Information Officer with Queensland Health, consumers are aware their data is being collected – and they expect it to be used a lot more than it currently is.

"The community is saying to us: why aren't you using my health data to improve my health outcomes?" McNeil said.

"We have to find ways to turn data into useful information so everyone can benefit."

Will Smart, Chief Information Officer for NHS England, was on the same page.

"Artificial intelligence, genomics and life sciences are the future of digital health – they offer us real opportunities if we can make data intelligence as part of the workflow," Smart said.

ANNUAL E-HEALTH RESEARCH COLLOQUIUM (CONTINUED)

Grahame Grieve, HL7's FHIR Product Director, discussed the importance of interoperability and said big changes to healthcare systems are needed to address many of our health data challenges. However, he said adoption is starting to happen, particularly with national health records and some clinical data repositories.

THE DIGITAL HEALTH FUTURE IS BRIGHT.

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

Attendees heard about:

- How our algorithm has been predicting patients' hospitalisation risk as part of the Australian Government's Health Care Homes trial
- An exciting project using neuroimaging to try predict the development of cerebral palsy
- The fantastic outcomes of a trial of our mobile health platform M♡THer to support women with diabetes and their clinicians
- An innovative collaboration with the University of Queensland setting health informatics on FHIR for students
- Progress on smart homes to help older people stay living independently for longer
- A glimpse at the world of digital genome engineering and next-generation tools for health
- A thought-provoking discussion on collecting information about Indigenous status in Australia
- Amazing new techniques being explored for treatments against cancers
- The progress of Activate TKR, a digital platform supporting total knee replacement care.

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

MANAGEMENT & RESEARCH LEADERSHIP

Dr David Hansen

CEO, Australian e-Health Research Centre

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

David is a member of the Australian Digital Health Agency Clinical and Technical Advisory Committee, Co-Chair of the National Clinical Terminology Service, Member of the National Steering Committee for the Australian Genomics Health Alliance and Chair of the Health Informatics Society of Australia (HISA).

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

Dr Michael Lawley

Group Leader, Health Informatics

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

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

Dr Jurgen Fripp

Group Leader, Biomedical Informatics

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

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

Dr Denis Bauer

Group Leader, Transformational Bioinformatics

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

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

Denis holds a Bachelor of Science from Germany, a PhD in Bioinformatics from the University of Queensland and a Certificate in Executive Management and Development from the University of New South Wales Business School. Her achievements include developing open-source machine learning cloud services that accelerate disease research, which is used by 10,000 researchers annually.

MANAGEMENT & RESEARCH LEADERSHIP (CONTINUED)

Dr Mohan Karunanithi

Group Leader, Health Services

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

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

Dr Rajiv Jayasena

Group Leader and Victorian Lead, Health System Analytics

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

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

Professor Yogesan Kanagasingam

Director, Australian Tele-health Research and Development Group

Professor Yogesan has developed medical technologies from bench to bed and one of his inventions is used by NASA in the International Space Station. Yogesan was an Australian of the Year finalist in 2015 and WA Business Leader of the Year finalist in 2014 for his contribution to medical sciences and blindness prevention.

He is a Visiting Scholar to Harvard University and Professor at the School of Medicine at the University of Notre Dame. He was a Fulbright Scholar to Stanford University School of Medicine and a NHMRC Research Fellow.

Dr Janet Fox

Business Development Manager

Janet has over 15 years of experience in strategic and applied research as well as business development across the health and biomedical sectors.

She has comprehensive experience in all aspects of research translation including commercialisation, licensing, IP strategy and protection, business development, industry engagement, commercial development and contract negotiation.

Highly skilled in both the strategic and operational aspects of research and commercialisation as well as a strong technical background, adding value to all aspects of the successful commercialisation and partnering of research outcomes.

NEWS AND COMMUNICATIONS

OUR RESEARCH WAS AGAIN BOTH NATIONALLY AND INTERNATIONALLY WELL-REPRESENTED THROUGHOUT THE YEAR:

- Our videostreaming app for premature babies was promoted through a CSIRO media release with Townsville Hospital, reaching more than 1.1M people through Seven News, Weekend Sunrise, ABC, 2GB radio and News Corp publications.
- Our hospitalisation risk algorithm for Health Care Homes was promoted through Precedence Health Care media releases, covered in PulseIT, RACGP and Aged Care Housing News and promoted through social media.
- Our mobile app to help burns victims with Fiona Stanley Hospital was promoted through a Channel 10 News Perth story with the WA Health Minister, a CSIRO blog and CSIRO social media, reaching more than 20,000 people.
- We were mentioned in an eHealth NSW media release about proof of concept projects, and covered in PulseIT, Healthcare IT News (Aus and US).
- Ontoserver was covered in an NCTS story in industry publication PulseIT.
- QAIHC published a media release and magazine article about our m-health collaboration, with Ray Mahoney interviewed live by Cairns Indigenous radio station Bumma Bippera Media 98.7FM.
- Our CUNE Scientific Reports paper was covered by ZDNet, on AEHRC.com and through social media.
- Our involvement in an MRFF-funded antimicrobial project OUTBREAK was covered on the CSIRO blog and AEHRC.com, reaching more than 23,000 people on social media.
- Healthcare IT News featured Justin Boyle on data analytics and Jana Vignarajan on our mobile app for burns victims.
- David Silvera's work with robots to support children on the autism spectrum was covered in Health Agenda and the Robots Champion website.
- Gen-Phen Insight GT-Scan, and cloud architecture insights were covered in Computerworld, the AWS Global Public Sector blog, and DevOps.com.
- Denis Bauer and Dana Bradford were panellists at Vivid Ideas: a Healthy Future panel, and promotion through CSIRO social media reached 185,000 people.
- Rosita Shishegar gave an interview on SBS in Persian on imaging and neurodegeneration.

Michael Lawley

David Ireland

AWARDS

OUR TEAMS WERE SUCCESSFUL IN WINNING AND PLACING IN A NUMBER OF AWARDS AGAIN THIS YEAR.

- David Ireland and collaborators had 2019 QLD iAward success:
  - Pain ROADMAP with MNHHS, CSIRO and UQ was awarded Research and Development Project of the Year, and merit recipient for both the Data Insights Innovation of the Year and Community Service Markets categories.
  - Virtual Companions for People with Autism was merit recipient for Research and Development Project of the Year.
- Michael Lawley won the International Award of Excellence at the SNOMED CT Expo for his contribution to the development of SNOMED CT.
- CALD Assist won the 2018 National iAwards PitchFest's Public Sector and Government category.
- The MICE mobile imaging app was a finalist in the WA Health Excellence Awards 2018.
- M♡THer won IHF/Austco Excellence Award for Quality and Safety in Patient-Centred Care (Gold).
- PD-BUDDy won the MSH pinnacle award. "Board Chair's Award for Excellence", and M♡THer won MSH Board Chair's Award in the Digital Innovations category.
- Sankalp Khanna and John Grimes were part of the team that won the ANZICS 2019 Critical Care Datathon, and Hamed Hassanzadeh was part of a team awarded Highly Commended.
- Anthony Nguyen et al's accepted MedInfo research paper on "A decision support system for pathology test result reviews in an emergency department to support patient safety and increase efficiency" was nominated as Award Quality.
- Amir Fazlollahi won the Best Poster Award for "The Next big Thing - Creating Change" at Convergence Conference, Brisbane 2019.
- Jurgen, Olivier, Sam, James, Pierrick, Vincent, Ying, Amir, Kaikai, Michael, Ibrahima, Marcela, Simon, Hugo & Parnesh were awarded the CSIRO H&B Outstanding Collaboration Award for their combined efforts of science delivery in the AD space.
- Bevan Koopman's "Extracting Cancer Mortality Statistics from Free-text Death Certificates: A View from the Trenches" won Best Short Paper at the Australasian Document Computer Symposium in New Zealand.
- Lee Reid won Best Paper Award at the PatchMI satellite event of MICCAI in Spain.

RESEARCH PROGRAM

The Australian e-Health Research Centre (AEHRC) is now a full health and biomedical informatics research program with over 100 scientists and engineers and over 30 students.

This program spans health informatics, covering data about patients, services and populations; biomedical informatics, using patient genomics and imaging data to personalise diagnosis and treatment; and health services, the use of technology in delivering services to patients.

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

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

Our research program is informed through strong partnerships with the health industry, including clinicians, researchers, health service executives and the health IT vendor community. With more than half our staff based at the Royal Brisbane Women's Hospital campus in Brisbane, our scientists and engineers have strong relationships with Queensland Health administrators, clinicians and researchers. Our growing teams in Sydney, Melbourne and Perth are building relationships into respective state health departments and we continue to work as a program across Australia. The AEHRC continues to deliver to national programs, with key projects with the Department of Health and the Australian Digital Health Agency. As CSIRO's digital health research program, the centre works with scientists from across CSIRO, contributing to projects in CSIRO's Health and Nutrition, Biosecurity, Probing Biosystems and Precision Health business units.

HEALTH INFORMATICS

The introduction of electronic health and medical records, including the national My Health Record, is increasing the demand for clinical information to be shared between health practitioners and with patients.

Our health informatics research develops and applies innovative tools and techniques for evidence-based solutions and strategies to support improved health outcomes. Our goal is to unleash the value in health data, including both electronic health records and administrative data sets, to improve patient outcomes and health system performance and productivity.

AEHRC scientists and engineers apply machine learning, natural language processing, formal logic, and statistical and simulation approaches to the collection, processing, analysis and sharing of health information for decision support, systems modelling and reporting.

HEALTH SYSTEM ANALYTICS

Our aim is to improve performance and sustainability of the Australian health system by transforming clinical and operational data to create knowledge with analytics, optimisation, real-time monitoring for decision support, and risk stratification tools, and to understand how evidence can be implemented in business-as-usual health practices in hospital and health services.

BIOMEDICAL INFORMATICS

New medical technologies, especially genomic and imaging technologies, are leading a revolution in the personalisation of diagnosis and treatment.

Our biomedical informatics research develops innovative technologies for the discovery and communication of meaningful patterns from new medical technologies. We aim to develop techniques to report and visualise complex biomedical information for clinical diagnosis and screening. This information can ensure precise diagnosis and appropriate treatment to reduce unnecessary treatment and improve outcomes. Our scientists and engineers use the simultaneous application of statistics, computer programming, and applied mathematics to develop solutions that communicate insights to clinicians and clinical researchers.

TRANSFORMATIONAL BIOINFORMATICS

The impending digital disruption through the rise of artificial intelligence and the exponential increase in data volumes pose a substantial challenge for the health and lifescience disciplines. Preparing Australia for this, the Transformational Bioinformatics group develops novel bioinformatics solutions for research and industry. We partner with international cloud providers, universities and startups to bring health innovation to Australia. We specifically focus on machine learning for population-scale 'omics (genomics, transcriptomics, methylomics) analysis as well as genome engineering for health and biosecurity applications.

HEALTH SERVICES

The increase in mobile technologies and high-bandwidth broadband is changing the way that services are provided in all walks of life – including health services.

Our health services researchers work with health service providers to develop internet-enabled models of care to overcome the burden of chronic disease and aged care. Our teams are trialling technologies to deliver health services through mobile health, and tele-health technologies for patients with conditions such as eye diseases, cardiac diseases, diabetes, stroke, and hip replacements.

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

HEALTH INFORMATICS

2018/19 SCIENCE AND IMPACT HIGHLIGHTS

- The AEHRC continues to partner with the Australian Digital Health Agency in the National Clinical Terminology Service. Over 50 companies and organisations have fee-free licenses to our terminology server, Ontoserver, for implementation of state-of-the-art support for clinical terminology in their e-health products.
- Use of Ontoserver is one of the core elements of Defence's JP2060 Phase 4 procurement requirements, which looks to deliver their next generation EMR platform.
- The MedTex (medical text analytics tool) was deployed within Queensland Health to process and analyse both the historical and live pathology feeds for cancer notifications reporting from public and private pathology laboratories across Queensland. A death certificate cause-of-death classification service was also deployed within the MedTex platform to supplement the cancer notifications reporting from pathology reports.
- Our Data Interoperability team is contributing to the Australian, Queensland and Melbourne Genomics Health Alliances to capture accurate clinical phenotypes – vital to ensuring that Australia will get full value from investments in genomics medicine. The standards developed as part of this work are in the process of being published internationally through the Global Alliance for Genomics and Health.
- The AEHRC is leading a national project for the Commonwealth Department of Health to develop a set of foundational standards for GP data. The GP Data Quality Foundations project is successfully collaborating with GP vendors and peak bodies to develop these standards.
- We continue to contribute to the National Health and Medical Research Council (NHMRC) Centre for Research Excellence in Digital Health in partnership with Macquarie University's Australian Institute for Health Innovation and the University of Melbourne.
- The AEHRC has partnered with the University of Queensland to introduce a Health Informatics on FHIR course for third year IT students. The course was led by CSIRO Distinguished Visiting Fellow Professor Mark Braunstein.

Health Informatics Group Leader: Dr Michael Lawley

Australia's healthcare system faces many challenges. One significant challenge is the increasing demand for clinical information to be shared between individual health practitioners, healthcare provider organisations and state and territory health departments. Our health informatics research develops and applies innovative tools and techniques for evidence-based solutions and strategies to support improved health outcomes. Our goal is to improve the quality of, and unleash the value in, health data, including electronic health records and administrative data sets, to improve patient outcomes and health system performance and productivity. We apply informatics, machine learning, natural language processing, and formal logic to problems involving decision support, systems modelling and integration, and reporting and analytics.

Health Data Interoperability Team Leader: Dr Alejandro Metke

Data is captured about patients in a number of different formats and electronic repositories using many different terminologies. Our technologies are targeted at understanding the information in data, whether the data is captured in an electronic health record, coded in a clinical database, captured from sensors, described in medical free text reports or even captured using imaging technology. Our team also works in genomics, specifically representing patient phenotype data using standards and terminologies. Our involvement in several genomics alliances in Australia and internationally has helped us position ourselves as leaders in this field.

Health Text Analytics Team Leader: Dr Anthony Nguyen

The Health Text Analytics team is focused on deriving value from electronic health data in terms of improving 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.

Health Data Engineering Team Leader: Derek Ireland

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

HEALTH DATA INTEROPERABILITY

Successful adoption of standard terminologies such as SNOMED CT and the Australian Medicines Terminology (AMT) is vital for enabling patient data to move between clinical systems in a safe way. Many systems across health organisations such as Queensland Health will be required to migrate from other code sets to SNOMED CT.

Our tools help with this migration and deal with complexities such as the level of detail in each code and gaps in the codes while still ensuring that high-quality data is captured.

We have developed significant national and international impact through our tools: the free SNOMED CT and AMT browser, Shrimp; the terminology mapping and subsetting tool, Snapper; the cloud-based terminology server, Ontoserver; and the reasoning engine, Snorocket.

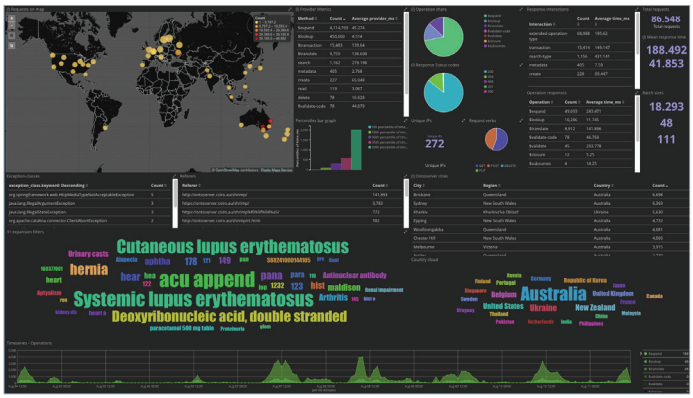
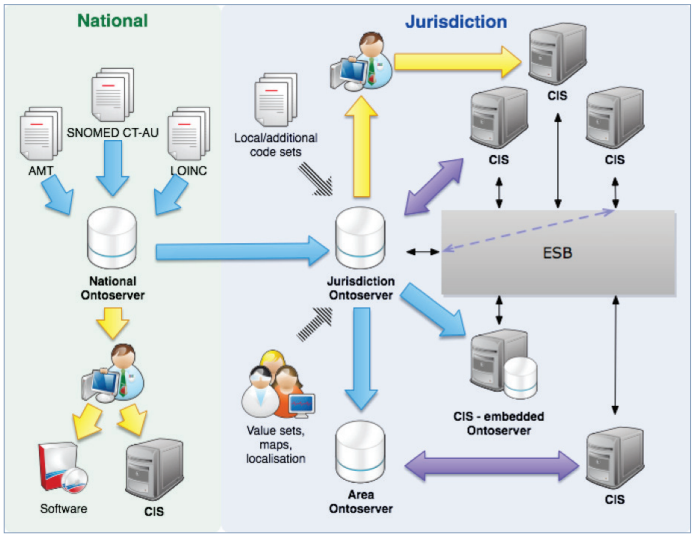


Figure 1. A typical seven days of Shrimp usage.

Figure 2. High-level architecture of the National Clinical Terminology Service.



A NATIONAL CLINICAL TERMINOLOGY SERVICE

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

Advantages to this approach include:

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

Through 2018/19 the team delivered six new versions of Ontoserver and are preparing for an upcoming major upgrade to the first normative version of FHIR (R4) in early 2019/20. We have also closely engaged with the FHIR community to clarify, refine and improve details of the Terminology Services subsystem of the HL7 FHIR Specification, and engaged closely with state jurisdictions and the vendor community through a series of very successful Connectathons and workshops to ensure the resulting service delivers what is needed.

There are currently 69 sub-licensees of Ontoserver through the NCTS, as well as commercial licensees in Switzerland and New Zealand, with the United Kingdom's National Health Service engaged in an extended proof-of-concept project.

HEALTH DATA INTEROPERABILITY (CONTINUED)

SNOMED CT IN THE QUEENSLAND DIGITAL HOSPITAL PROJECT

The Queensland digital hospital project introduced SNOMED CT terminology as part of the implementation of an integrated Electronic Medical Record. As part of this project, we worked with the Princess Alexandra Hospital's (PAH) digital hospital program on several collaborative projects.

An early outcome was to work with the PAH and the Australian Digital Health Agency to release an extension to SNOMED CT-AU containing more than 100 new procedure codes required to support the pioneering use of SNOMED CT in the deployment of the Cerner SurgiNet product.

Further work continues to expand the SNOMED CT reference set for SurgiNet as the Cerner product is deployed in other Queensland hospitals.

SNOMED CT-encoded data for secondary reporting purposes

One part of the broader project dealt with the problem of continued reporting of emergency department non-admitted patients after the switch from the use of ICD-10-AM to SNOMED CT. The result of this was a tool, snoMAP, which extends the coverage of SNOMED CT from a relatively small subset of clinical findings to all relevant codes clinicians will need to use to document patient records in the emergency department setting. The goal was to repurpose the original SNOMED CT-encoded patient data and maintain its true value for clinical care delivery and to ensure it complies with and qualifies for activity-based funding.

The digital hospital program has now been rolled out across six Queensland hospitals and this number is growing. These additional hospitals have begun to use snoMAP, and with snoMAP content, both SNOMED concepts and ICD-10-AM codes updated twice per month, PAH and other Queensland digital hospitals can submit data for activity-based funding in near real time.

Injury surveillance and reporting

This approach to using SNOMED CT-encoded data and snoMAP has now been extended to include specific subsets suited to injury surveillance and reporting.

Clinical cohorts

Work continues on developing particular subsets of SNOMED CT for analysing data based on patient cohorts. Early work has investigated the use of snoMAP to produce routine reports for particular patient cohorts, such as patients presenting with diabetes or mental health issues.

This work will help preserve the routine and ad-hoc reporting at a local hospital level, in the same way that data analysts previously produced 'dashboard' reports using ICD-10-AM-encoded data.

Allied health

Terminology work has continued supporting the development of statewide data collections for the allied health sector. Various allied health disciplines unified their approach to data capture and reporting, and are standardising using SNOMED CT in the Cerner product. At present, the legacy termsets have been mapped to SNOMED CT (n=2000 terms).

Approximately 292 new concept requests and/or new synonym additions to existing terms have been generated by the allied health discipline groups and have been submitted to the Australian Digital Health Agency for addition and release. Of these, all have now been actioned and released in SNOMED CT AU.

Work involving the expansion of the initial mapset of 2000 concepts which will increase the expressivity of data capture in allied Health records has now been completed. A much richer and descriptive data collection will enable expanded measures of the effectiveness and clinical outcomes achieved by the allied health professions, rather than only service event-based metrics.

RACS MALT GOES SNOMED CT-NATIVE

During 2018/19 we continued our collaboration with the Royal Australasian College of Surgeons (RACS) and the use of a native implementation of SNOMED CT-AU in their Morbidity Audit Logbook Tool (MALT) including the maintenance of aggregation maps to support ongoing reporting processes from the MALT data.

To date, over 400 new concepts have been created and released in SNOMED CT AU. RACS is also considering broadening the use of SNOMED CT, so MALT will allow their users to also capture data relevant to diagnoses and outcomes.

This value set is now available as a reference set through the Australian Digital Health Agency's SNOMED CT AU regular release cycle.

GENOMICS

During 2018/2019 the AEHRC consolidated valuable working relationships with a number of genomic health alliances, including Queensland Genomics, Melbourne Genomics and Australian Genomics.

The Queensland Genomics Health Alliance

Queensland Genomics is a $25M initiative to support the introduction of genomics into clinical care in Queensland.

The AEHRC partnered with the Queensland Institute of Medical Research (QIMR), the Queensland Facility for Advanced Bioinformatics, The University of Queensland and the Queensland University of Technology to lead the Genomics Information Management program in Phase 1.

The program undertook research activities to identify the key information management requirements for introducing genomics into the Queensland healthcare system. This included working with the clinical projects to look at specific information management requirements. Based on some of these requirements, the CSIRO developed a prototype genomic test ordering system using SMART on FHIR, focusing on understanding the interfaces involved and the interoperability requirements. Other work included the development of a tool to automate the processing of pathology reports to support understanding infectious disease outbreaks in a timely manner. QIMR and QFAB developed prototypes for cloud-based storage of genomics data and the curation of variants in genome sequences.

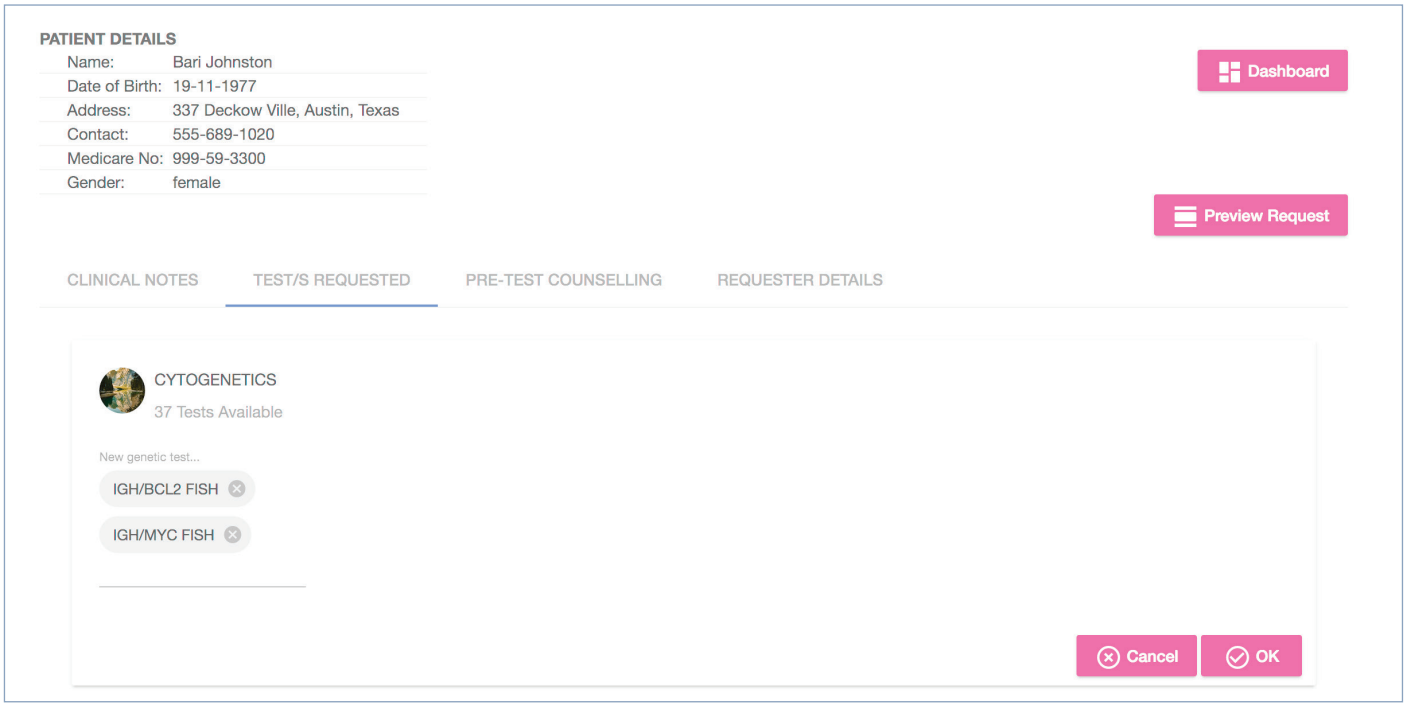
The Melbourne Genomics Health Alliance

The AEHRC continues to lead the CSIRO's involvement in the Melbourne Genomics Health Alliance. Our bioinformatics team has delivered a number of bioinformatics tools for the GenoVic solution. The Health Data Interoperability seconded two team members into the Alliance to support the development of the GenoVic platform and the use of FHIR and SNOMED CT within the solution.

The Australia Genomics Health Alliance

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

Figure 3. SMART on FHIR genomic test ordering prototype developed as part of the Genomics Information Management program in the Queensland Genomics Health Alliance.



HEALTH DATA INTEROPERABILITY (CONTINUED)

Standardising trial data

One of the main issues in Australian Genomics is that the clinical flagship projects capture phenotypic data in different ways, despite using the same platform (REDCap). This makes it difficult to reuse the data or interoperate with other systems.

This problem was solved by designing and implementing the FHIRCap platform, a novel solution based on a domain specific transformation rules language that allows expressing how the REDCap data should be represented in standardised format, in this case the FHIR standard, and mapping any bespoke codes to standardised terminologies, such as SNOMED CT and HPO.

For new flagships, the transformation to FHIR has been facilitated by carefully designing the REDCap forms and avoiding the use of bespoke codes and free text where possible. Instead, standard codes are used enabled by a REDCap plugin that allows choosing codes from standard terminologies using autocomplete fields. The plugin uses our terminology server, Ontoserver, to implement the search functionality.

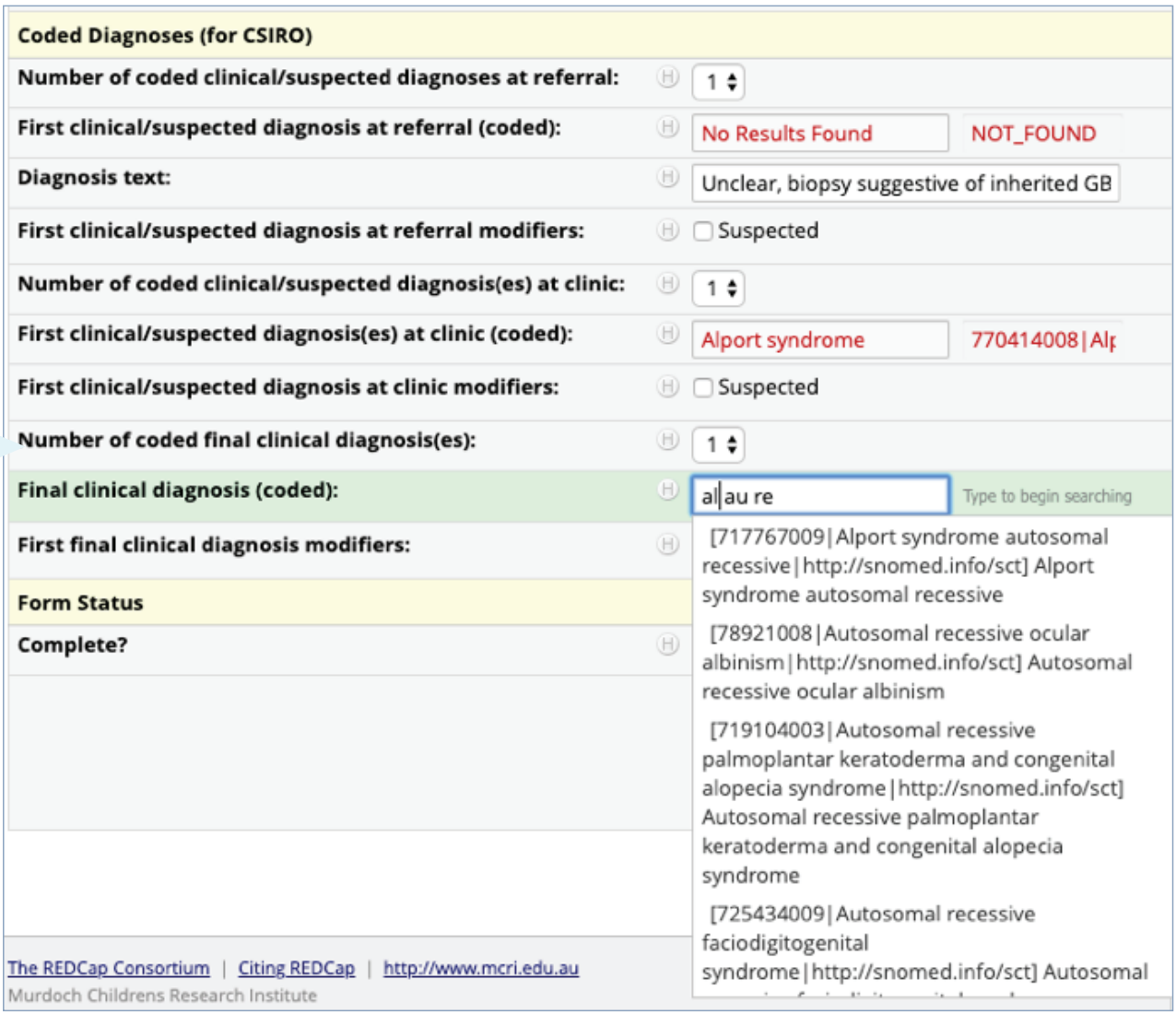
Broadening support for genomics terminologies

Many terminologies used in genomics are distributed in Web Ontology Language (OWL) format. FHIR has no native support for OWL ontologies and some of the characteristics of OWL are challenging to represent in FHIR code systems. A generic transformation between OWL and FHIR code systems was designed and implemented. This allows supporting terminologies such as the Human Phenotype Ontology, the Phenotypic Quality Ontology, the Foundational Model of Anatomy and Orphanet in Ontoserver.

Aligning terminologies

In an effort to commence the standardisation of genomic data collections, significant work has been done looking at the alignment and the creation of a map between the Human Phenotype Ontology and SNOMED CT. A high-quality initial version of the map, prioritised based on the most used terms, has been developed and work in this space continues.

Figure 4. The REDCap Ontoserver plugin used in the Australian Genomics forms.



Defining minimum clinical data sets

Development has commenced of flagship-specific FHIR value sets based on the data currently being collected. It is hoped that these value sets will form the basis for ongoing development of SNOMED CT genomics reference sets for use and release in the international edition. The value sets have been deployed in an Australian Genomics Ontoserver instance and can be browsed using a value set viewer extension of Shrimp, our terminology server browser.

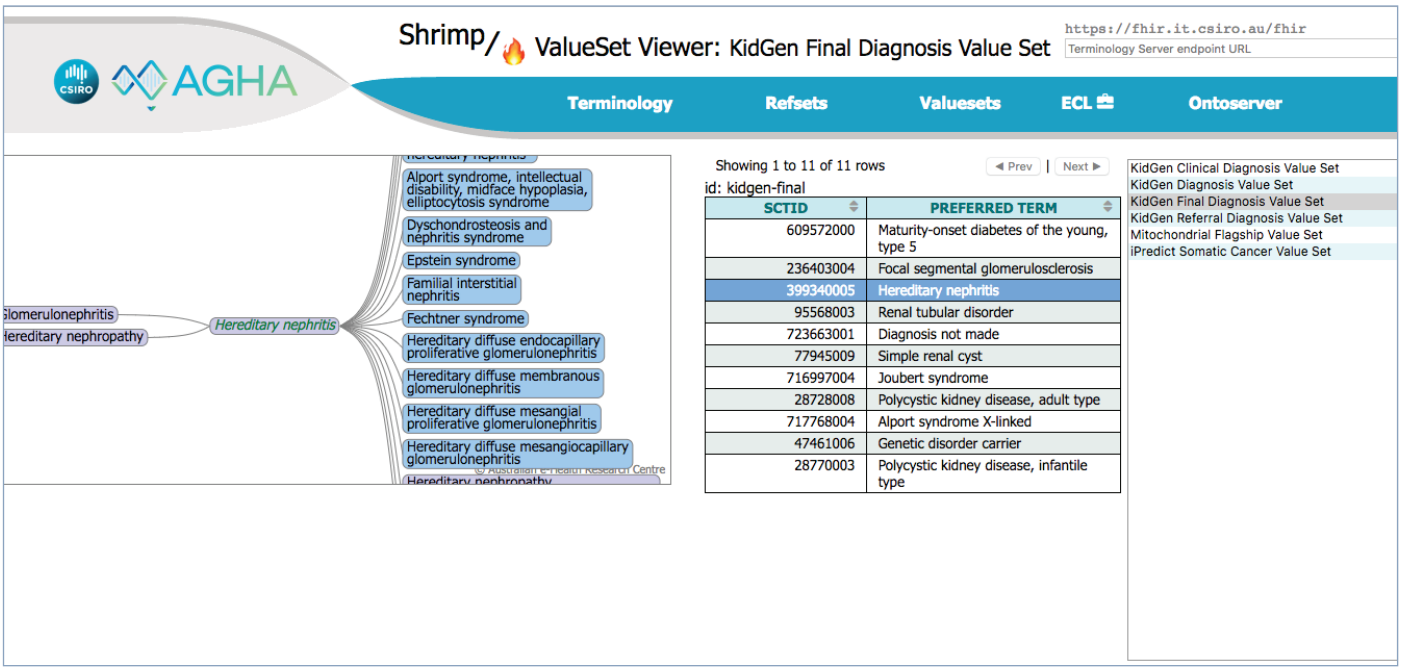
The Global Alliance for Genomics and Health

The AEHRC contributes to the the Clinical & Phenotype Data Capture group in the Global Alliance for Genomics and Health (GA4GH). One of the goals of this group is creating standards that support the standardisation of clinical phenotype information.

One of the standards that has been under development in this area is Phenopackets, an open standard for sharing disease and phenotype information, aimed mostly at the research community. The Phenopackets on FHIR project is looking at representing the Phenopackets standard using a FHIR implementation guide.

The use of FHIR will help drive the uptake of the standard within the clinical community and will also facilitate the integration with EHR systems. Ultimately, Phenopackets on FHIR will promote the interoperability of patient phenotype information from many different sources, including EHRs, journals and research tools such as REDCap.

Figure 5. The value set viewer implemented for Australian Genomics.



HEALTH DATA INTEROPERABILITY (CONTINUED)

ANALYTICS USING SNOMED CT AND FHIR

Analytics

Traditional analytics solutions are inadequate or unhelpful in the specialised task of querying clinical data enhanced with complex clinical terminologies such as SNOMED CT. Improving the tools available in this space is an important component of the overall strategy of improving the value proposition of adopting standard clinical terminologies within health information systems.

Development of a data analytics platform capable of answering both traditional and terminology-augmented analytic queries has commenced. The platform leverages FHIR to provide standardised interfaces for getting data in and out of the system. The system leverages the power of Ontoserver for resolving terminology queries, and uses contemporary distributed processing frameworks to enable the harmonisation of clinical records and terminology query results at runtime.

Work has also been carried out on user interfaces for exploring and querying FHIR data. More work is planned in the area of specialised user interfaces for constructing queries of clinical terminology, including the preparation of value sets for use in cohort definition, grouping and filtering.

The concept of an API acting as the primary integration point for the data warehouse opens up some interesting possibilities relating to integration with third-party knowledge resources, such as machine learning models.

Standardised hook services could be configured to generate suggestions to augment the data in the warehouse, similar to the way that FHIR CDS Hooks currently work to augment EHR workflow with decision support information. This could be used to integrate services in areas such as risk stratification and natural language processing to surface derived information for analytic query.

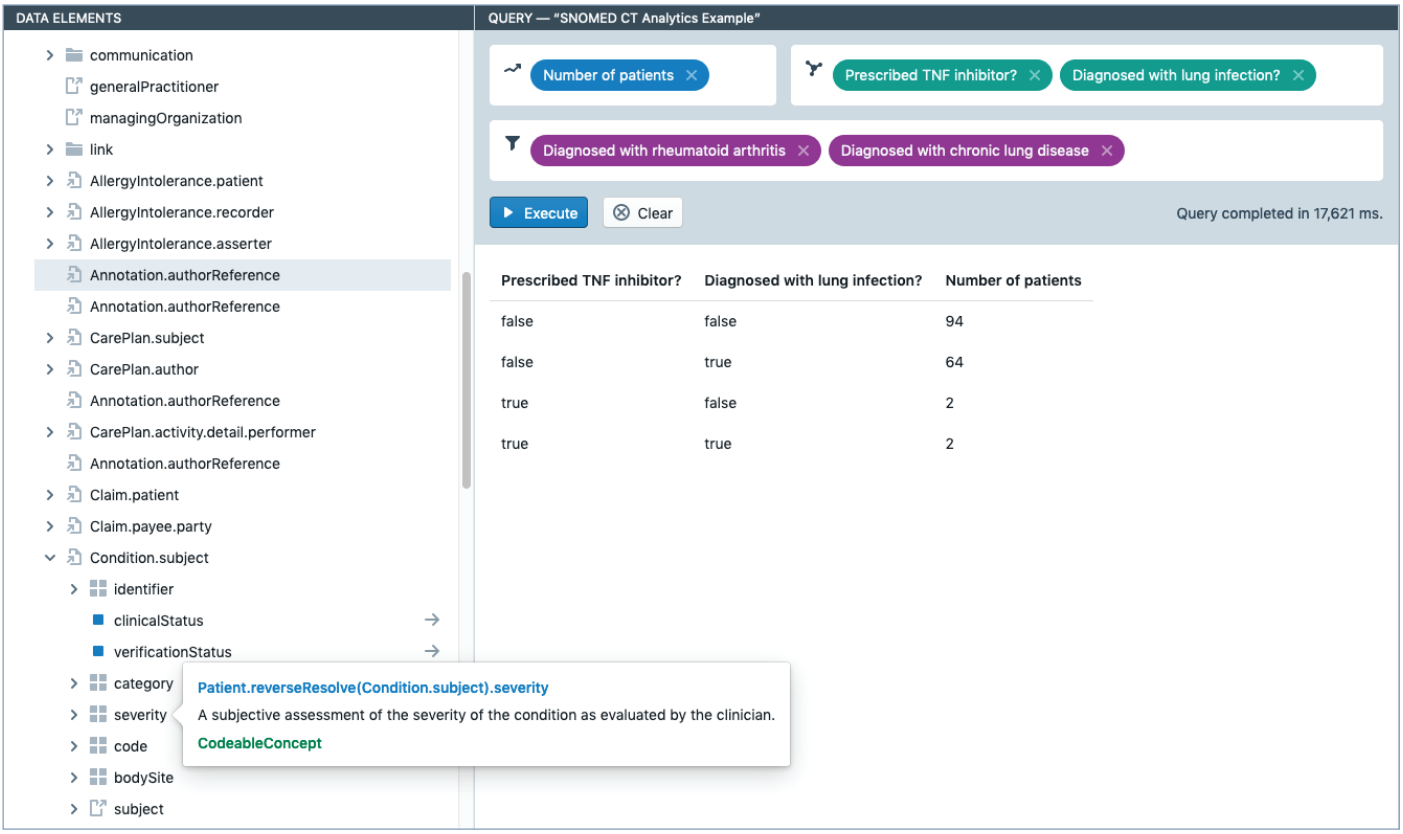
Another concept that we are working on in relation to the analytics API is centred around a standardised interface for third-party app authorisation.

This could be used to extend the functionality of incumbent analytics software solutions, in the same way that SMART-on-FHIR currently allows for the extension of the functionality of EHR systems.

Scopes within these assertions about authorisation could reflect concepts that are specific to analytic use cases, such as whether the user is authorised to access individual records.

Information about provenance and consents relating to patient records could also be brought into the warehouse and be used to inform whether authorisation should be granted to particular users, based on their roles.

Figure 6. A prototype explorer interface developed as part of the analytics research activities



PRIMARY CARE DATA QUALITY FOUNDATIONS

CSIRO was commissioned in 2018 by the Australian Government Department of Health to undertake a series of projects known as the Primary Care Data Quality Foundations Programme. The programme was to be delivered through collaboration with the clinical profession, software industry, Australian Digital Health Agency, and the Australian Institute of Health and Welfare (AIHW).

The objectives of the programme were to define the foundation data standards in primary care to support better clinical outcomes, enhance the usefulness of information in the practice record and improve interoperability of health information shared with other health care providers and organisations.

The success of the overall programme was dependent upon reaching consensus with the profession and industry of the core clinical information which needs to be consistently recorded by the clinician (in a structured and coded format) in the practice record and exchanged by the practice system in a standard format.

Each of these projects delivered critical components to support improvements to data quality in primary care. The projects are complimentary and designed to address the data quality challenges ranging from data standards to education and training and targeting support for the primary care practices, practice software systems and data extract providers.

One of the key principles was to ensure the programme leveraged and supported existing professional standards, industry standards and existing national programs. In particular, this programme supported a number of Royal Australian College of General Practice (RACGP) standards, programs and initiatives:

- RACGP Practice Standards for accreditation
- RACGP Practice Technology and Management Committee, especially the minimum requirements for Practice Software
- Primary Care Collaboratives joint Project with National Aboriginal Community Controlled Health Organisation (NACCHO)
- RACGP Quality Initiatives

The projects also progress Australia's National Digital Health Strategy which proposes seven priority outcomes to be achieved by 2022. One of these is to achieve high-quality data with a commonly understood meaning that can be used with confidence. The interoperability of clinical data is essential to high-quality, sustainable healthcare. This means that patient data should be collected in standard ways and can be shared in real time with them and their providers.

The Primary Care Data Quality Foundations project has four component projects, as summarised below:

Project 1 - Primary Care Data Dictionary and SNOMED CT Value Sets

- Increase standardisation of data definitions in primary care systems through the development of an agreed core clinical primary care data dictionary. Document: Primary Care Data Quality Foundations- Data Dictionary Release 1
- Adoption of a common clinical language in primary care systems through the development of the Primary Care SNOMED CT value sets.

Project 2 - Primary Care Data Exchange and Query

- Standardise exchange of the agreed core clinical information through an agreed FHIR Specification – FHIR Implementation Guide Primary Care au Practice to Practice Record Transfer.
- Increase the utility of data exchanged for reporting and analytics through the development of guidance on how to use SNOMED CT for analytics and reporting.

Project 3 - Software Industry Implementation Support

Support the adoption of the primary care data dictionary, value sets, and FHIR Implementation Guide, through workshops, Connectathons and guidance.

Project 4 - Primary Care Education and Training

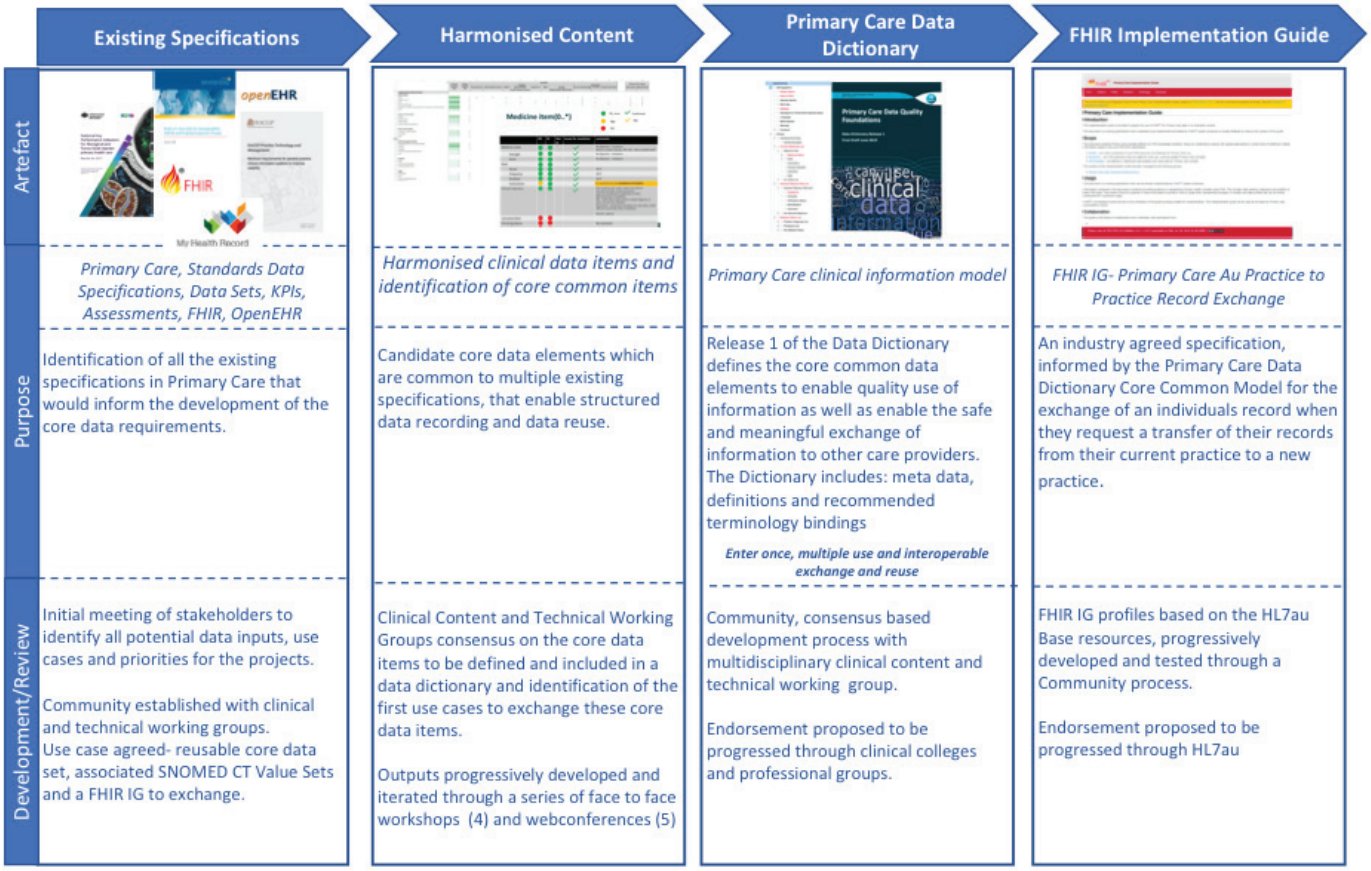
- Increase awareness and understanding of the value of structured and coded information through the development of train-the-trainer education material, quick reference guides, and more.
- Increase understanding of the most important areas in the record that should be structured and coded – core clinical data – through focussed training material.

HEALTH DATA INTEROPERABILITY (CONTINUED)

The core principles for the approach to delivery include:

1. Open and transparent 2. Standards based 3. Consensus driven 4. Agile and iterative

Figure 7. Community collaboration process for development of FHIR Implementation Guides and SNOMED CT Value Sets



Primary care data dictionary

In order to start to standardise health data, which can reduce the burden on the industry and profession, this project co-developed clinical data sets and specifications to support primary care.

Building upon the lessons of the UK, NZ and the US, the CSIRO was contracted to work with the RACGP, ACCRM, ADHA, and MSIA to develop an agreed Primary Care Data set to be used by all clinical systems for the exchange of clinical data.

The project was to deliver the foundation for a Primary Care Data Dictionary which harmonises the different data definitions used across the Department of Health, industry and the clinical practice as well as the SNOMED CT-AU based data sets including, but not limited to, RACGP Record Standards, My Health Record Specifications, PHN Reporting requirements, PIP, and National KPIs.

Primary care FHIR implementation guide

There are a number of different approaches to exchanging or querying the data from practice management systems. The aim of the project is to standardise the approach to retrieving data or exchanging data from primary care systems through agreeing a specification using the FHIR Standard. To support the use of SNOMED CT, data aggregation guidance and example data sets were also developed to enable the reporting and analytics of the structured and coded information.

Primary care practice management system adoption

Core to the programme was the support of industry in the development, testing and adoption of the project outputs.

Primary care practice education and training

To support the profession in understanding the benefit of recording and maintaining clinical data in their clinical information system in a structured and coded way, an education and training plan and supporting learning materials were developed.

The plan and materials were designed and developed in collaboration with the peak profession bodies with training and education to be delivered by the RACGP, ACCRM, Australian Primary Health Care Nurses Association (APNA) and Australian Association of Practice Management (AAPM). Primary Health Networks may also deliver training for practices and will be consulted as part of this project. Training materials will also be published online on agreed websites.

HEALTH INFORMATICS ON FHIR WITH THE UNIVERSITY OF QUEENSLAND

The AEHRC partnered with the University of Queensland to offer a Health Informatics on FHIR course to third and fourth year IT/Software Engineering students in the 2nd semester of 2018. The course was led by CSIRO Distinguished Visitor, Professor Mark Braunstein, from Georgia Tech in Atlanta, USA. Ten students successfully undertook the course which involved Professor Braunstein's Health Informatics on FHIR online course, a series of guest lectures from local and interstate experts and the development of a SMART on FHIR app as part of a group project with clinical mentors, in this case from the University of Queensland Medical School.

In collaboration with the University of Queensland Medical School, the students chose to develop a platform to support case-based learning used in the medical school curricula, allowing medical students to learn about using an electronic health record and clinical apps during the regular teaching period. The app was positively received both by the medical students who evaluated its use as part of the project, and the medical school staff who worked with the students in its design.

The health informatics course received strong evaluations from the students who undertook it, as well as from the medical school staff who participated as subject-matter experts. The University of Queensland ITEE has confirmed they will continue with the Health Informatics on FHIR studio course for third and fourth year students again in 2019. Professor Mark Braunstein will return from the United States in June to run the course, in collaboration with a lecturer from the University of Queensland IT School, in anticipation of the course becoming a permanent part of the ITEE School curriculum in 2020.

The AEHRC software engineers are currently building an expanded version of the case-based learning platform initially developed by the IT students, for further evaluation and use by the Medical School.

KEY COLLABORATORS:

- Australian Digital Health Agency / National eHealth Transition Authority
- Royal Australasian College of Surgeons
- Princess Alexandra Hospital, Metro South HHS
- Australian Genomics, Queensland Genomics and Melbourne Genomics
- Jamieson Trauma Institute
- The University of Queensland
- NHS Digital.

HIGHLIGHTS FOR 2018/19:

- Continued development of Ontoserver for the NCTS and other licensees with the R4 version of HL7's FHIR APIs and syndication support.
- Contributed to the refinement of the HL7 FHIR Terminology Services API standard.
- Organised FHIR Connectathons in Australia (NCTS), NZ (HL7 NZ), and the UK (NHS Digital).
- Expanded the snoMAP tool as it has been taken up at additional sites throughout Queensland.
- Added new features to FHIRCap and the FHIR Analytics tool to implement the first analytics use case with the KidGen Flagship in Australian Genomics.
- Added support for OWL-based ontologies in Ontoserver to support genomics projects.
- Delivery of a Health Informatics on FHIR Course with the University of Queensland.
- Successful delivery of phase one of the Primary Care Data Quality Foundations project with very positive feedback from across the health IT sector, and setting the benchmark for a FHIR community process in Australia.

AIMS FOR 2019/20:

- Expand and improve terminology-enabled data analytics.
- Develop enhanced algorithms for automated analysis of terminology quality metrics to improve data quality.
- Develop more sophisticated auto-mapping strategies in Ontoserver to be utilised via Snapper.
- Develop assistive technologies that will support the clinician community to capture accurate, codeable data for documentation of patient records.
- Extend our automated techniques for developing aggregation-based maps for reporting and data analytics.
- Build on the successful roll-out of Ontoserver as the NCTS terminology server platform-of-choice through international adoption and licensing.
- Promote the adoption of the new Phenopackets on FHIR standard to facilitate the standardisation and sharing of clinical data.

HEALTH TEXT ANALYTICS

Electronic health records (EHR) are expected to enable better health outcomes and improved efficiencies in our health services. The majority of health information in EHRs is "locked" in narrative documents, such as discharge summaries, radiology reports, etc. This information is valuable for clinical decision support and secondary use such as for population health monitoring and reporting. However, in many cases, it is either inaccessible and remains underutilised, or its large volume hinders manual processing.

As a consequence, extracting key clinical information from medical narratives is often performed retrospectively with delays that potentially undermine data quality and patient safety.

The Health Text Analytics team is developing and applying advanced natural language processing, information retrieval, and machine learning techniques, along with standard clinical terminology (e.g. SNOMED CT) semantics and reasoning, to provide meaningful and accurate computational interpretation of clinical free-text.

Our solutions have been developed in partnership with healthcare practitioners from cancer registries and hospital radiology and emergency medicine departments. Working with health industry stakeholders allows our health text analytics solutions to leverage the wealth of clinical free-text reports to enhance healthcare data quality and aid in decision support and reporting.

Figure 1: Artificial intelligence capabilities for understanding and reasoning with clinical text data with an emphasis on standard clinical terminologies for data interoperability and analytics.

AUTOMATING CANCER DATA REGISTRIES TO ENHANCE DATA QUALITY

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

In partnership with the Queensland Cancer Control Analysis Team (QCCAT) at Queensland Health, we are extracting and classifying information about cancers from the free-text contents of histopathology reports and death certificates for cancer notifications, synoptic reporting and cancer staging. This is enabling QCCAT to build a real-time, virtual Cancer Register that processes new histopathology reports from public and private pathology laboratories from across Queensland as well as death certificates as they become available. This processed information enhances the data quality of the Register and provides the capacity to support key activities such as cancer monitoring and health service planning and research.

This medical text analytic service uses the AEHRC Medtex platform to automatically read and analyse pathology reports and death certificates.

RECONCILING MEDICAL RECORDS TO PREVENT MISDIAGNOSES

The checking of radiology imaging and pathology laboratory reports to ensure abnormalities or positive results, respectively, are not missed and that patients receive appropriate follow-up once discharged from the Emergency Department (ED) is an essential but laborious task. Due to a busy ED and resourcing issues, it can often be days after the patient's initial presentation to the ED that this checking process is performed. This process results in time inefficiencies with delays in reporting, delays in checking reports, and delays in recalling patients. A timelier and efficient process is therefore required to improve patient outcomes and staff resources.

In partnership with the Royal Brisbane and Women's Hospital and The Prince Charles Hospital EDs, we have developed algorithms and models to reliably identify abnormal or positive results from radiology and pathology reports, and link these with patients' disposition as recorded in the Emergency Department information system to provide decision support to the currently manual checking process. This ensures that misdiagnoses are detected in a timely manner and acted on appropriately. Future work will develop software to demonstrate the clinical and patient benefits arising from the information technology-based solution.

DIAGNOSIS CODING FROM ELECTRONIC HEALTH RECORDS FOR QUALITY ASSURANCE AUDITS

Clinical coders abstract relevant information from patients' medical records and decide which diagnoses and procedures meet the criteria for coding as per Australian Coding Standards. The process mainly relies on manual inspections and experience-based judgements from clinical coders, and the effort required for information abstraction is labour- and time-intensive and prone to human errors. In partnership with the Gold Coast University Hospital and Health Service, we have developed algorithms and models for automating the diagnosis coding (ICD-10-AM) process from hospital progress notes. Promising results were achieved from using CSIRO's snoMAP for mapping SNOMED CT concepts identified in free-text progress notes to ICD-10-AM diagnosis codes.

Furthermore, in partnership with the Queensland Cancer Control Analysis Team (QCCAT), a death certificate ICD-10-AM cause-of-death classification service was developed using deep learning technology. This service was deployed as part of the Medtex platform for cancer notifications reporting at Queensland Health to process and classify real-time incoming death certificates for the Cancer Register.

Figure 2: Health search and analytics using text, concepts, annotations, and SNOMED CT subsumption querying.

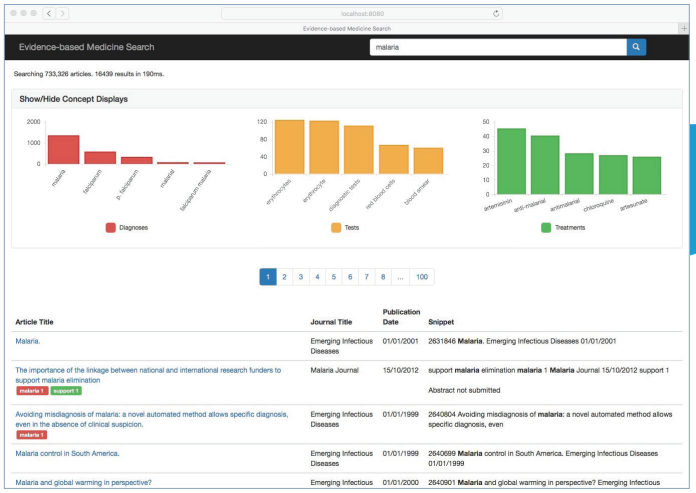
HEALTH RECORD SEARCH AND ANALYTICS

Search technologies are critical to enable clinical staff to rapidly and effectively access patient information contained in free-text medical records. Health search is challenging as it suffers from the semantic gap problem: the mismatch between the raw data and the way a human interprets it. Valuable domain knowledge explicitly represented in structured knowledge resources such as ontologies (e.g., SNOMED CT) can be leveraged to support such semantic inferences. The focus of our research is on health record searching and analytics using text, concepts, annotations, and SNOMED CT subsumption and relation querying.

To support the need for evidence-based medicine, we have developed a search engine that provides clinicians easy access to the vast and ever-changing body of medical literature and clinical trials.

A key, novel aspect of the search engine is that it is specifically tailored around the three clinical tasks of searching for diagnoses, searching for treatments and searching for tests. All results are displayed, and the clinician can interact with the system according to these three clinical tasks. An empirical evaluation of the systems showed both better quality results and time savings from the task-oriented approach.

Figure 3: Task-oriented search engine for evidence-based medicine.



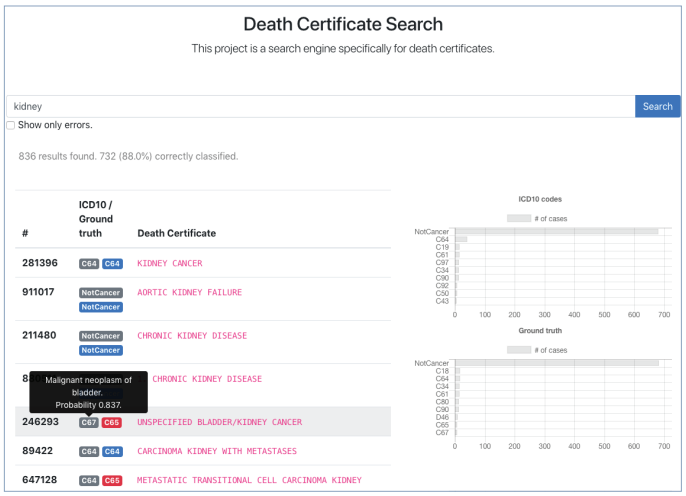
Death certificates provide an invaluable source of mortality information. To realise this value, automated methods for classifying cancer types and searching certificates are needed.

Together with the Queensland Cancer Control Analysis Team, we have developed a deep learning and information retrieval system that allows cancer registers to extract cancer mortality statistics from free-text death certificates. The system comprises a deep learning classifier to identify cancer-related deaths, a search engine to allow users to search death certificates and classifier results, and a deployment architecture that aims to handle issues of scalability and complexity.

Empirically, the system can accurately identify cancer deaths for both common and rare cancers. The use of the search engine helps cancer analysts drill into specific results and convince them of the utility of using an automated approach. The system is now deployed within Queensland Health to process all death certificates for cancer monitoring and control.

HEALTH TEXT ANALYTICS (CONTINUED)

Figure 4: Death certificate classification and search.



NHMRC CENTRE OF RESEARCH EXCELLENCE IN DIGITAL HEALTH

We are part of the NHMRC Centre of Research Excellence in Digital Health, in partnership with Macquarie University Australian Institute for Health Innovation and the University of Melbourne, and will be working with scientists from around Australia on clinical decision support and automating the production of systematic reviews. Clinicians are often required to make decisions in the absence of best-practice evidence. As a result, treatment success of individuals with complex comorbidities or treatment history may depend on the clinician's experience.

The project proposes to use the "Green Button" concept, which leverages aggregate Electronic Health Record (EHR) data, for real-time, personalised comparative effectiveness information to empower clinicians in making evidence-based decisions in the absence of published guidelines. Using this button, clinicians are able to view and evaluate treatment approaches and outcome of "patients like theirs" in the context of their hospital or other contributing institutions. In particular, we will enhance the structured data in EHRs with text analytics of clinical text to better support clinical decision making at point-of-care, not only to reduce clinical care pathway variations but also to provide health outcomes evidence for those that do.

Systematic reviews play a key role in evidence-based medicine, informing practice and policy. Existing technology to assist with systematic review production has largely ignored the search stages of the systemic review. Existing search engine research is also often not applicable to the unique task of systematic reviews. This project will develop novel search engine technology to significantly improve the process of producing systematic reviews. This will directly impact how systematic reviews are produced and, consequently, the downstream impact of health decisions made on the basis of these reviews.

COLLABORATORS:

- Queensland Cancer Control Analysis Team (QCCAT), Queensland Health
- Department of Emergency Medicine, Royal Brisbane and Women's Hospital
- Department of Emergency Medicine, The Prince Charles Hospital
- Department of Emergency Medicine, Logan Hospital
- Gold Coast Hospital and Health Service
- Institute for Evidence-Based Healthcare, Bond University
- Data Science group, University of Queensland
- Plexa Medical.

HIGHLIGHTS FOR 2018/19:

- Developed and deployed death certificate cause-of-death classification service using deep learning technologies for the Queensland Cancer Register within Queensland Health.
- Extended and deployed Medtex's cancer stage and synoptic reporting capabilities within Queensland Health by automatically extracting TNM (tumour-nodes-metastasis) cancer stages from histopathology reports for the Queensland Cancer Register.
- Developed a proof-of-concept decision support system for microbiology test result review in an emergency department to support patient safety and increase efficiency. Text mining and clinical terminology semantics were highly effective at identifying abnormal test results, reducing the number of test results for review by 92%. Furthermore, the system reconciled antibiotic sensitivities with documented antibiotic prescriptions in discharge summaries to identify patient follow-ups with a 91% F-measure – allowing for the accurate prioritisation of cases for review.
- Developed an automated method to match patients to eligible clinical trials based on their electronic patient record.

AIMS FOR 2019/20:

- Automatically extract and infer important clinical indicators for cancers to extend the cancer stage and synoptic reporting capabilities within Queensland Health.
- Develop FHIR-based decision support applications for clinical interaction e.g., ED test result checking, clinical trial matching.
- Investigate the explainability and application of deep learning for developing a good computational representation of both the structured and unstructured free-text data in EHRs that can be leveraged across a range of clinical classification tasks – patient classification, disease risk stratification and treatment outcome.
- Extend the health text search and analytic technology solutions to other health applications and report types.
- Together with Plexa Medical, deploy an automated system to match clinical trials to eligible patients.

PHD STUDENT PROFILES

Harry Scells

AEHRC PhD Top-Up, Scholarship Queensland University of Technology

Improving systematic review creation with information retrieval

Systematic reviews, in particular medical systematic reviews, are time consuming and costly to produce. The largest contributing factors to the time and monetary costs are the searching (including the formulation of queries) and screening processes. These initial processes involve researchers reading the abstracts of thousands and sometimes hundreds of thousands of research articles to determine if the retrieved articles should be included or excluded from the systematic review. This research explores automatic methodologies to reduce the workload relating to the searching and screening processes.

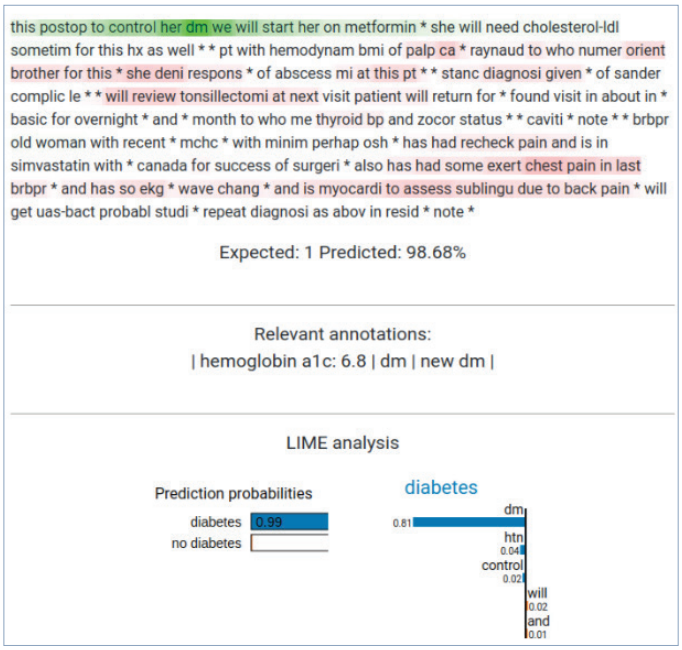
Anton van der Vegt

AEHRC PhD Top-Up, Scholarship University of Queensland

Bridging the Human-Task Cognitive Gap. A Theoretical Framework Applied to Medical Search

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

Figure 5: Explaining deep learning predictions with visualisations.



HEALTH DATA ENGINEERING

Our Health Data Engineering team is a dedicated team of software engineers who work with our scientists across the Australian e-Health Research Centre in delivering solutions to our customers and partners. With specialist skills in mobile app design and development and web-based software development, as well as specialist knowledge in health IT standards such as HL7 and FHIR, the team contributes to projects across the AEHRC.

Over the past 12 months the team has continued to develop our mobile phone platform to support our mobile health projects, worked with our clinical terminology specialists to deliver on the National Clinical Terminology Service, developed a new version of our Medtex medical narrative processing software, and developed FHIR-based resources for use across our projects. The team also continues to support a number of clinical trials with various clinical trial software packages.

MOBILE HEALTHCARE DELIVERY PLATFORM

Many of the projects from the Mobile Health group involve testing the effectiveness of new care models delivered through mobile technologies like smartphones and wearables and sometimes passive sensors. Our team manages a common framework known as the MoTER platform to deliver these projects, attempting to maximise reuse while not hindering innovation. The platform consists of iOS and Android applications and a web portal for clinicians to review the collected data. This year the platform has been redesigned to be an ecosystem of co-operating FHIR components.

AEHRC ON FHIR

Activities include:

- participating in Connectathons and Health "Hacks" to build skills and awareness, using the Medications Resource to represent medications from the Australian Medicines Terminology and other sources, using ValueSets for medication input in mobile apps
- experimenting with the use of FHIR ConceptMaps for Medtex
- investigating the use of FHIR to represent and exchange clinical trials data, both as a view of ODM / CDISC data and natively
- dynamic generation of Angular-based data entry user interfaces from FHIR profiles
- an extended version of the HAPI FHIR Server, Sapphire, that delegates to Ontoserver for its terminology subsystem to take advantage of its advanced SNOMED capabilities
- medical student case review training tool with a basic FHIR EMR/case viewer application and case authoring tool application
- wrapping prediction algorithms as a FHIR CDS Hooks Service.

A SMART on FHIR reference implementation has been developed incorporating OAUTH against third-party systems (such as Google) and the AEHRC FHIR server. The first application to use this reference implementation will be a genomic test ordering system.

DELIVERY OF TECHNOLOGY INTO THE HEALTH SYSTEM

Our team provides the bridge between research outcomes and deployment of technology into the health system by productising, system integration, deployment and support. As an example, PAPT has been made into a product and is deployed into Queensland Health and licensed to Telstra Health, greatly increasing its impact.

The Readmission RISK Stratification system is deployed at Logan and being used daily for decision support. With the rapid adoption of FHIR the team is working towards using FHIR and CDS Hooks as business as usual in our delivery strategy.

CLINICAL TRIAL SUPPORT

We provide support for clinical trial data management systems like REDCap and OpenClinica as well as custom data collection solutions. REDCap has been extended to support using an external FHIR-based terminology server for coded data fields.

BIOMEDICAL INFORMATICS

2018/19 SCIENCE AND IMPACT HIGHLIGHTS

- The first multi-centre clinical trial using MRI to guide prostate radiotherapy delivery for 25 men has been completed with excellent results. This work has now been accepted for publication and is based on several important technologies developed by the Biomedical Informatics Group.
- In our multi-centre neurodevelopmental studies, over 250 infants have undergone brain MRI in the neonatal period. NHMRC funding has been secured for further neurodevelopmental and MRI follow-up of the same children at 6 years, with recruitment about to commence.
- We were involved in an international working group to develop the centiloid framework to standardise quantitative measures of amyloid from PET images. Validation of our cloud imaging pipeline (CapAIBL) confirmed it was able to provide reliable centiloid estimates cross sectionally as well as longitudinally.
- Our groups managed to deliver on an increasing number of projects from across an extensive network of collaborations, including several large NHMRC clinical studies and trials. In addition, the recognition of our capabilities in clinical study data management is increasing with multiple studies now requesting and relying on our support and expertise.
- More than 30 journal publications.

Biomedical Informatics Group Leader: Jurgen Fripp

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

Neuroimaging Team Leader: Sam Burnham

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

Medical Image Analysis Team Leader: Jason Dowling

The Medical Image Analysis team is leading a paradigm shift in radiology from qualitative to (semi-) quantitative imaging and the development of a new generation of 'imaging biomarkers'. The technology developed turns images into information that is used for earlier detection of diseases and improved diagnostic accuracy. These technologies are used in trials across a number of clinical areas including prostate radiotherapy planning, cartilage health assessment, characterising cerebral palsy risk in infants, surgical planning and paediatric MR-based lung assessment.

Biostatistics Team Leader: James Doecke

On the cover of Nature magazine, the title reads "Brain inspired circuits meets machine-learning processes in hybrid AI chip". Such articles using machine learning and artificial intelligence methodologies are becoming more common. With the massive amounts of data that are available, statistical techniques and the statisticians behind them are working to solve some of the world's biggest problems in human health. With specialists in bioinformatics, Bayesian biostatistics, neuroimaging and classical biostatistics our team is well placed to analyse biomedical data with the view to interpret some of the world's most important medical research questions.

MEDICAL IMAGE ANALYSIS

Medical imaging is critical in achieving further improvements in outcomes for patients and in driving efficiencies across the health system. The medical image analysis team combines expertise in 3D image processing, machine learning and medical physics with nationwide clinical collaborations to automatically extract and present information for clinicians and researchers, enabling optimal clinical decision making and treatment delivery. Projects within the team range across the lifespan (pre-term infants to diseases of old age) and from head (brain pathways) to toe (musculoskeletal analysis).

PAEDIATRIC NEUROIMAGING

Very preterm infants (born before 31 weeks gestation) have a high risk of an adverse neurodevelopmental outcome. Approximately 5% of these infants will be diagnosed with cerebral palsy (CP), and half of them have later learning and behavioural difficulties. Diagnosis of cerebral palsy is currently made on average at 19 months corrected age, diagnosis of learning and behavioural difficulties even later. Earlier diagnosis would enable more effective tailored therapy during the first two years of life, when the brain has a large capacity for repair.

We are developing approaches to model normal infant brain neurodevelopment using MRI, and identify abnormal development. This includes methods to improve image quality, automatically delineate brain structures of interest to observe their growth and changes in their microstructure, and the extent to which different parts of the brain communicate and identify other biomarkers associated with developmental abnormalities. In collaboration with the University of Queensland and the Royal Brisbane and Women's Hospital, we are using these methods to predict the potential for adverse neurodevelopment earlier, and to more accurately identify those in need of therapy.

More than 250 infants have had brain MRI in the neonatal period, and 107 have completed neurodevelopmental follow-up assessment at two years. Funding has been secured for further neurodevelopmental and MRI follow-up of the same children at six years, with recruitment about to commence.

We are also using brain MRI to develop methods to quantify the degree of brain injury and brain developmental status of children with CP relative to neurotypical children. In partnership with the University of Queensland and the Cerebral Palsy Alliance, we are using these methods to predict clinical function and to assess neuroplasticity in response to intervention. An observational study of children aged 8-10 years is underway (Predict-CP), aiming to determine the relationship between brain development and clinical function, as well as two randomised controlled trials of early intervention for infants aged three months to two years at high risk of CP (GAME and REACH). A multi-site randomised controlled intervention trial for children with CP aged six to 18 years (HABIT-ILE), led by our collaborators at the University of Queensland, has commenced in Brisbane, Sydney, and Perth. An observational study of the early natural history of CP has commenced with the University of Melbourne.

This research will enable major advances in the management of preterm babies and children with CP by providing a means to identify those therapies that will provide the greatest benefit to the individual child. It has the potential to reduce the burden of CP on the health system, while increasing the integration of these children into society.

NEUROSURGICAL PLANNING SYSTEM: CONSULT

CONSULT aims to reduce rates of adverse events in neurosurgery by using cutting-edge brain mapping techniques, including advanced functional magnetic resonance imaging (MRI) and diffusion MRI tractography. The software produces a 3D model of a patient's brain and its wiring patterns. Neurosurgeons can then interact with this 3D model to plan the safest angle and depth to "cut" to cure patients without inducing critical injuries. The model and plans integrate with surgical-guidance technology, providing surgical teams with real-time feedback on progress and potentially imminent safety issues during surgery itself.

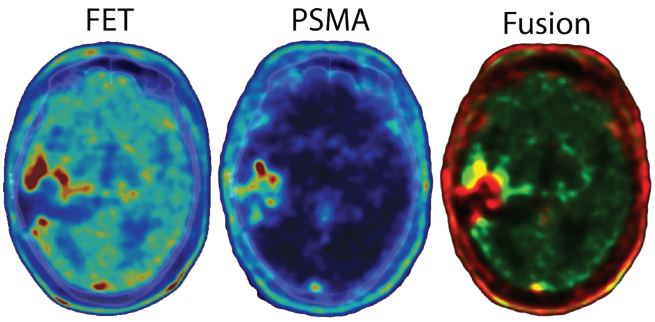
CONSULT aims to make brain surgery safer, more effective, and allow surgeons to treat patients previously considered too high-risk. This work is performed in conjunction with clinical partners, including radiologists and neurosurgeons at prominent Australian hospitals, and funded through grants from Advance Queensland (Research Fellowship), the Royal Australian and New Zealand College of Radiologists, and RBWH Foundation (Diamond Care Grant).

DEVELOPING THERANOSTICS FOR DIFFICULT TO TREAT CANCERS

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

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

Figure 1: Co-registered 18F-FET and 68Ga-PSMA images acquired in a patient with high grade glioma. Co-registration allows the efficacy of PSMA as a therapy to be predicted based on overlap with the diagnostic 18F-FET image.



DUAL-ACQUISITION OF 18F-FDOPA AND 18F-FMISO IN HIGH GRADE BRAIN CANCERS

Positron emission tomography offers invaluable information in planning the treatment of high grade primary brain tumours. For example, 18F-FDOPA PET highlights regions of metabolically active tumour protected by an intact blood-brain-barrier, and 18F-FMISO PET highlights regions of hypoxia. Targeting both regions during surgical resection and external beam radiotherapy is critical to improving patient outcomes, however, the logistical strain on nuclear medicine departments and the physical strain on heavily sick patients of two separate scanning sessions makes acquiring both images unlikely.

We have previously developed dual-tracer acquisition schemes based on kinetic modelling of dynamic PET data to acquire 18F-FDOPA PET and 18F-FMISO PET images in the same scanning session and validated these schemes in mouse models of primary brain cancers. The current project in collaboration with QIMR Berghofer consists of a five-patient trial to translate our work to the clinic.

MUSCULOSKELETAL IMAGE ANALYSIS: CHONDRALHEALTH AND MRHIPS

The ChondralHealth project aims to develop image processing techniques for MRI of human joints (knee, hip and shoulder) for non-invasive assessment of common chronic conditions. These conditions include osteoarthritis, a joint disease characterised by the breakdown of articular cartilage and the underlying bone. The disease's exact pathophysiology is not well understood and more research is required to identify imaging biomarkers related to early degenerative changes.

We developed algorithms for automated segmentation of joint cartilages from MRI scans and used it to identify useful morphological and biochemical quantitative descriptors of cartilage health. We are running a clinical trial with prominent clinical partner (Steadman Philippon Research Institute, USA) to validate these measures in pre-clinical setting.

The developed methods for bone and cartilage segmentation constitute a backbone technology for a newly started project "MR Hip Intervention and Planning System" (mrHIPS). This software aims to facilitate decision making in conservative management and surgical interventions for hip joint disorders. The technology enables bone lesion visualisation and quantification of bone lesions and soft tissue damage, as well as a framework for modelling of hip joint kinematics using 3D bone and soft tissue data. We started evaluating novel image acquisition protocols using a cutting-edge 7T MRI scanner at the University of Queensland and obtained high quality data for generation of detailed models of hip anatomy and kinematics.

Both projects have been supported by Siemens Healthineers, Germany, who work with us on translating the technology to clinical environments to improve patient diagnosis and clinical management.

MRI-BASED PAEDIATRIC LUNG STRUCTURE AND FUNCTION ASSESSMENT

This project is a collaboration with Queensland Children's Hospital, Siemens Healthineers, and the Herston Imaging Research Facility, and aims to improve health outcomes for children with cystic fibrosis (CF) and ataxia-telangiectasia (A-T) by using MRI to provide information on lung status.

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

To address this clinical need we are developing image acquisition methods and software to extract quantitative disease status metrics from MRI. This work is supported by a CSIRO OCE postdoc position and external funding from the AT Children's Project.

MEDICAL IMAGE ANALYSIS (CONTINUED)

MRI-ALONE RADIATION THERAPY PLANNING FOR PROSTATE CANCER

In collaboration with the Calvary Mater Newcastle Hospital and funding from the Prostate Cancer Foundation Australia and NSW Cancer Council, we have developed the first atlas-based method to map realistic electron densities to MRI scans for dose calculations. This method is now being used in the clinic for the first time to refine radiotherapy planning during treatment to reduce side effects of prostate cancer patients. These improvements are also leading to cost savings from the reduced need to manage side effects.

During the past year we have undertaken a Phase II multi-centre prospective trial for MRI-alone localised prostate cancer external beam radiation therapy (ANZCTR trial: ACTRN12616001653459). This trial has now finished and the results have been accepted for publication.

IMPROVING RADIOTHERAPY TREATMENT CLINICAL TRIAL QUALITY ASSURANCE

Radiotherapy is a well-established, cost-effective treatment with an evidence-based indication for approximately 50% of cancer patients. The weakest link in treatment is the definition of treatment volumes (contouring). Lack of accuracy and consistency in clinical trial contouring has been shown to result in reduced patient outcomes. However, manual review of contouring is resource intensive, expensive and for advanced treatments unachievable in a timely fashion.

This NHMRC-funded project, in collaboration with major Australian radiation oncology centres, involves developing the first automated approach to contouring assessment using four large clinical trial datasets with the aim of changing practice for future studies and enabling consistent assessment in the clinic. This software is currently being adapted for a national clinical trial (NINJA, ACTRN12618001806257).

COLLABORATORS:

- Royal Melbourne Hospital
- Queensland Institute of Medical Research
- McCusker Foundation
- Queensland Cerebral Palsy and Rehabilitation Research Centre
- Siemens Healthineers
- Steadman Philippon Research Institute
- Queensland Children's Hospital
- Telethon Kids Institute
- Royal Brisbane and Women's Hospital
- Queensland Cerebral Palsy and Rehabilitation Research Centre
- Stella Maris Institute, Pisa
- Ingham Institute for Applied Medical Research
- Calvary Mater Newcastle Hospital
- Sir Charles Gairdner Hospital
- Liverpool and Macarthur Cancer Services
- Universities of Queensland, Newcastle, New South Wales, Western Australia, Melbourne, Monash, Sydney, South Australia and Wollongong
- University of Barcelona, Spain
- Brisbrain and Spine
- GenesisCare
- Xing Technologies.

HIGHLIGHTS FOR 2018/19:

- Journal papers in top rated medical imaging and clinical journals.
- Successful grant funding, including NHMRC, RANZCR, RBWH Foundation.
- Successful CAPEX funding for the establishment of a radiopharmaceutical research space.
- Commencement of a $5.1M joint venture with GenesisCare.
- Invitation to speak at the conference Consilium, Australia's premier think tank with a focus on new directions for health policy in Australia.
- ChondralHealth software delivered to Siemens for internal evaluation.
- Commencement of a NHMRC Project Grant for following up with a cohort born preterm at six years.
- Alex M. Pagnozzi, et al. Best Scientific Poster Award, American Academy for Cerebral Palsy and Developmental Medicine 71st Annual Meeting 2017, Montreal.
- Lee Reid: People's Choice Award and CSIRO Accelerator Award at Impact 7, Melbourne.
- International multi-centre prospective clinical trial for MRI-alone, external beam radiation therapy for localised prostate cancer.
- Initiation of a new project aimed at MRI-based non-invasive lung structure assessment for children with cystic fibrosis.
- Development of improved MRI methods.
- Presented the lung MRI for assessment of cystic fibrosis at the ANZ Siemens MRI user group.
- $2.3M Cystic Fibrosis Foundation grant awarded in full.
- Invited talk on recent advances in lung MRI for assessment of cystic fibrosis at the 2019 symposium organised by Vertex Pharmaceuticals featuring international clinical experts.
- Initiated collaboration with the Ataxia-Telangiectasia Society and the University of Nottingham.

AIMS FOR 2019/20:

- MRI-based non-invasive and zero radiation paediatric lung structure and function evaluation (for CT and A-T).
- Development and validation of methods for automatic clinical trial quality assurance and linked information extraction from retrospective radiation oncology data sources.
- Gain insights into the neuroplasticity in response to speech therapy programs.
- Development of pipelines for resolution enhancement, segmentation and labelling for neonatal MRI data.
- Completion of multi-tracer PET acquisition trial.
- Clinical validation of the CONSULT platform for neurosurgical planning.
- Evaluation of ChondralHealth software in a multicentre study.
- Development of automatic quantitative MRI reports for children with cerebral palsy and infants at risk of cerebral palsy.
- Develop approaches to predict adverse outcomes from neurosurgery in adults using structural and/or diffusion MRI.
- Start development of motion correction methods to improve the analysis of dynamic image data.
- Validation of methods for contrast synthesis and segmentation based on deep learning.
- Segmentation tools for retrospective mining of radiation oncology imaging data.
- Publishing the results on the lung MRI for assessment of cystic fibrosis and ataxia-telangiectasia.
- Develop approaches to automatically score lung disease in lung MRI.
- Deploy the lung MRI protocol on a scanner at the Queensland Children's Hospital and acquire a large amount of data for the ELO study (Early Life Origins of CF lung disease).

PHD STUDENT HIGHLIGHT

Jessica Bugeja

University of Queensland

Biochemical MR sequences provide a method for quantification of the compositional and structural molecular characteristics of articular cartilage. *T2* and *T2** mapping of cartilage relaxometry values can assess early cartilage degeneration by quantifying water content and permeability, and the integrity of the extra cellular matrix (ECM).
The overall aim of this research project is to investigate quantitative MR imaging (biochemical biomarkers, *T2* and *T2** mapping) of articular cartilage, to analyze and model the progression of the degeneration of hip and knee joint cartilage leading to OA. The outcome will be a method that allows a more accurate trajectory for the progression of OA from quantitative MRI data and an adaptive segmentation of hip and knee joint cartilage and bone for clinical assessment of unusual joint angles. The application of this research in clinical practice could have the potential to aide in the diagnosis and treatment of OA in the hip and knee joint.

NEUROIMAGING

HEALTHY AGEING AND ALZHEIMER'S DISEASE RESEARCH

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

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

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

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

- where different tests are used across (or even within) studies, we are able to align data by mapping the data from one test to mimic that of the other test. We achieve this using missing data strategies that capitalise on the underlying structure and relationships of the data sets we are harmonising.
- helping to define and refine the centiloid scale. Amyloid imaging through Positron Emission Tomography (PET), has produced remarkably consistent qualitative findings across a large number of centres, however there has been considerable variability in the quantitative findings of different radio-tracers and their different retention rates. We were involved in an international working group to develop a framework (centiloid scale) to standardise quantitative measures of amyloid from PET images. We have demonstrated that our imaging pipeline (CapAIBL) is able to provide reliable centiloid estimates cross sectionally as well as longitudinally.

ADOPIC is a NIH-funded project that involves harmonising retrospective data from three large international longitudinal cohorts, including AIBL. After harmonisation, statistical approaches will be used to investigate onset and progression of various biomarkers.

Alzheimer's disease network (ADNet)

ADNeT is funded by the National Health and Medical Research Council National Institute for Dementia Research. Its primary aim is to establish an integrated network of dementia researchers, clinicians and health service providers to enable ongoing, high-quality translation of research into clinical care for Australians living with cognitive impairment and dementia. In addition, ADNeT will enable fast recruitment of trial-ready research participants, and will support participants through their involvement in clinical trials.

This is a large collaboration with 12 partners and includes an ADNeT registry, memory clinics, and screening and trials. We will be providing support for the data collection, storage and harmonisation for the whole ADNeT ecosystem as well as providing the image quantification and clinical translation for the thousands of medical images associated with this novel and far-reaching project.

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

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

We are applying cutting edge imaging technologies to examine the neurobiological features associated with high risk for dementia, and identify the changes that lead to a patient's transition from high risk to cognitive impairment. The combined use of genetic risk scores and neurobiological markers creates a potential prognostic marker for dementia development. Outcomes of the study will inform and establish a platform for future intervention programs that target preventing and treating dementia. Currently the baseline cohort of 237 subjects has been recruited for the PISA imaging study.

Sterling's Dream: cholinergic degeneration

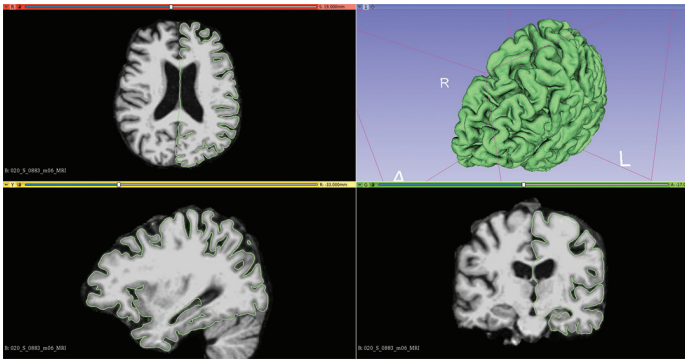
Cholinesterase inhibitors (ChEIs) are a major class of cognitive enhancing drugs designed to target the symptomatic treatment of Alzheimer's disease. This is based on the knowledge that cholinergic degeneration of the basal forebrain is a hallmark pathological feature of Alzheimer's with specific vulnerability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

In collaboration with Queensland Brain Institute (QBI) and The Prince Charles Hospital, we will investigate novel PET tracers to gain a better understanding of the differences in the characteristics of healthy brains compared with those with early stages of Alzheimer's disease. So far, 15 subjects have been recruited in Sterling's Dream, and 11 have been imaged using both Florebetaben, to measure their amyloid burden, and FEOBV, to measure their cholinergic degeneration.

Cortical surface reconstruction from brain MR images

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

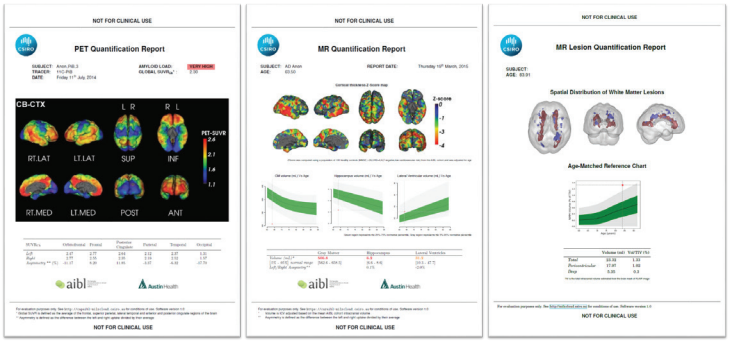
Figure 1: Example of reconstructed surface from an MR image.



UK Biobank: functional connectivity patterns and depressive symptoms

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

Figure 2: Example quantitative reports for PET analysis (CapAIBL), MR morphometry (CurAIBL) and FLAIR white matter hyperintensity segmentation (HIST)



COLLABORATORS:

- ADNeT team
- ADOPIC Research Team (UCSF, WashU, UniMelb)
- E-DADS Research Team (UCL, FDF)
- Australian Imaging Biomarkers and Lifestyle (AIBL) study
- QIMR Berghofer Medical Research Institute
- Florey Institute of Neuroscience and Mental Health
- Nuclear Medicine and Centre for PET, Austin Health
- University of Melbourne
- Edith Cowan University
- University of Wollongong
- University of Sydney
- Macquarie University
- University of Western Australia
- F. Hoffmann La Roche
- Janssen
- UCSF
- WashU
- Mayo Clinic
- Oxford University
- Harvard Medical School.

NEUROIMAGING (CONTINUED)

HIGHLIGHTS FOR 2018/19:

- Two successful NHMRC grants and one successful NIH Grant.
- Co-authored paper in evaluating the new CTE dementia definition in Lancet Neurology (IF 27.1).
- 18 published journal articles and 10 conference papers.

AIMS FOR 2019/20:

- Translation of CapAIBL and CurAIBL to Maxwell Plus.
- Development of novel deep learning methods for image quantification.
- Harmonisation of multidisciplinary data across sites for ADNeT and ADOPIC.
- Validation of CapAIBL for use with novel tracers.
- Translation of disease biomarkers into personalised stage identification and progression forecasts in AD.

PHD STUDENTS:

Biting Yu

University of Wollongong

Magnetic resonance imaging (MRI) is a widely used medical imaging modality that can be configured to provide different contrast between tissues in the human body. By setting different scanning parameters, each MR imaging modality reflects the unique visual characteristic of the scanned body part, which benefits medical image analysis from different perspectives. To utilise the complementary information from different imaging modalities, cross-modality MR image synthesis has been sought after and attracted increased research interest recently. This project aims to develop novel techniques in deep learning applied to medical image synthesis for the purpose of improving current image analysis workflows.

Cathryn McKenzie

University of Western Australia

Cognitive reserve is the hypothesised capacity for adapting to physiological changes in the brain, such as those caused by ageing or disease pathology, in order to maintain normal cognitive functioning. Cognitive reserve can be assessed as the difference between an individual's observed test performance, and the performance predicted based on structural brain health (such as volume of brain matter). Cognitive reserve, as indexed by this residual approach, has been found to be related to factors thought to build reserve such as education, cognitive decline and future dementia diagnosis, independently of brain health, and increased efficiency of brain networks as measured by functional magnetic resonance imaging. While this approach has shown initial promise, some aspects that might improve our understanding of the cognitive reserve construct remain unexplored. This project will address these gaps in the current research.

Jeremy Beaumont

Rennes 1 University, France

The acquisition of magnetic resonance (MR) images with different contrasts (T1, T2, diffusion, ...) is today a standard procedure in both research and clinical practice. Typically, images are acquired in separate measurements and then pre-processing steps are needed to spatially normalise the data before analysis. In this context, magnetic resonance imaging (MRI) sequences that provide, in a single acquisition, co-registered datasets with different contrasts are of interest to reduce the amount of data processing and to minimise loss of information due to interpolation and other possible confounding effects. This project focus is on the study of the MP2RAGE sequence, optimised with fluid and white matter suppression, to provide multiple contrasts and quantitative measurements of tissue magnetic properties in a single MR acquisition.

BIOSTATISTICS

AUSTRALIAN DEMENTIA NETWORK (ADNET)

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

Our team is key in analysing data from the Australian Imaging Biomarkers and Lifestyle (AIBL) study, which is working to identify and validate biomarkers for the early detection and treatment of neurodegenerative disorders and psychoses. By bringing together industry, end users and healthcare providers, our AIBL researchers aim to develop and commercialise our research findings to deliver changes to treatment in medical and health care practices. Playing the lead role in setting up the database for the Australian Dementia Network (ADNeT), team members work with multiple people across different data domains to integrate large volumes of data for others to easily access, and set up protocols such that future data collections will have integrity for research and analyses.

Kicking off in 2019, ADNeT aims to recruit about 4000 participants over the next five years from around Australia, and will host data from imaging, biomarkers and lifestyle similar to the AIBL study from all across the country.

This year our research in biomarkers for the early detection of Alzheimer's disease led to 17 publications and 17 conference presentations. Key research from the team led to many strong publications, including papers in top ranking journals such as Neurology and Lancet Neurology.

NEUROPSYCHOLOGY AND ITS DISORDERS

Members of the team play a key role in a further project studying disorders of cognition and mental health, including Parkinson's disease, Alzheimer's disease and cerebral palsy. Providing key statistical support and project guidance, team members analyse project data to align with research hypotheses and define novel pathways into disease ethology.

In the Alzheimer's disease space, the team conduct research into biomarkers from CSF to align with PET imaging. Research from this project has led to a real bench-to-bedside outcome, with results from biomarker studies guiding decisions made on disease diagnosis in the clinic. In the Parkinson's disease space, the team assesses genomic biomarkers that align with the presence of disease physiology, and in cerebral palsy, the team provides statistical guidance on MRI data to assess cognitive function from children with the disease. This research has led to six journal publications in high-ranking journals.

INSTRUMENTAL RELATIONSHIP WITH PHARMACEUTICAL COMPANIES

Our team is working closely with international pharmaceutical companies Roche, Biogen, Eisai and Abbvie to assess both the early detection of biomarkers predictive of Alzheimer's disease pathology, and the cognitive trajectory of the disease from its very early stages (prodromal and pre-clinical) through to late stage clinical AD.

Research is focused around changes in cognition, blood and CSF-based biomarkers and pathological proteins via PET imaging. Along with collaborators from world-leading laboratories, our team members are instrumental in round table discussions to discuss the best way forward in conducting research across multiple countries.

INSTRUMENTAL BENCH TO BEDSIDE RESULTS FOR INFLAMMATORY BOWEL DISEASE

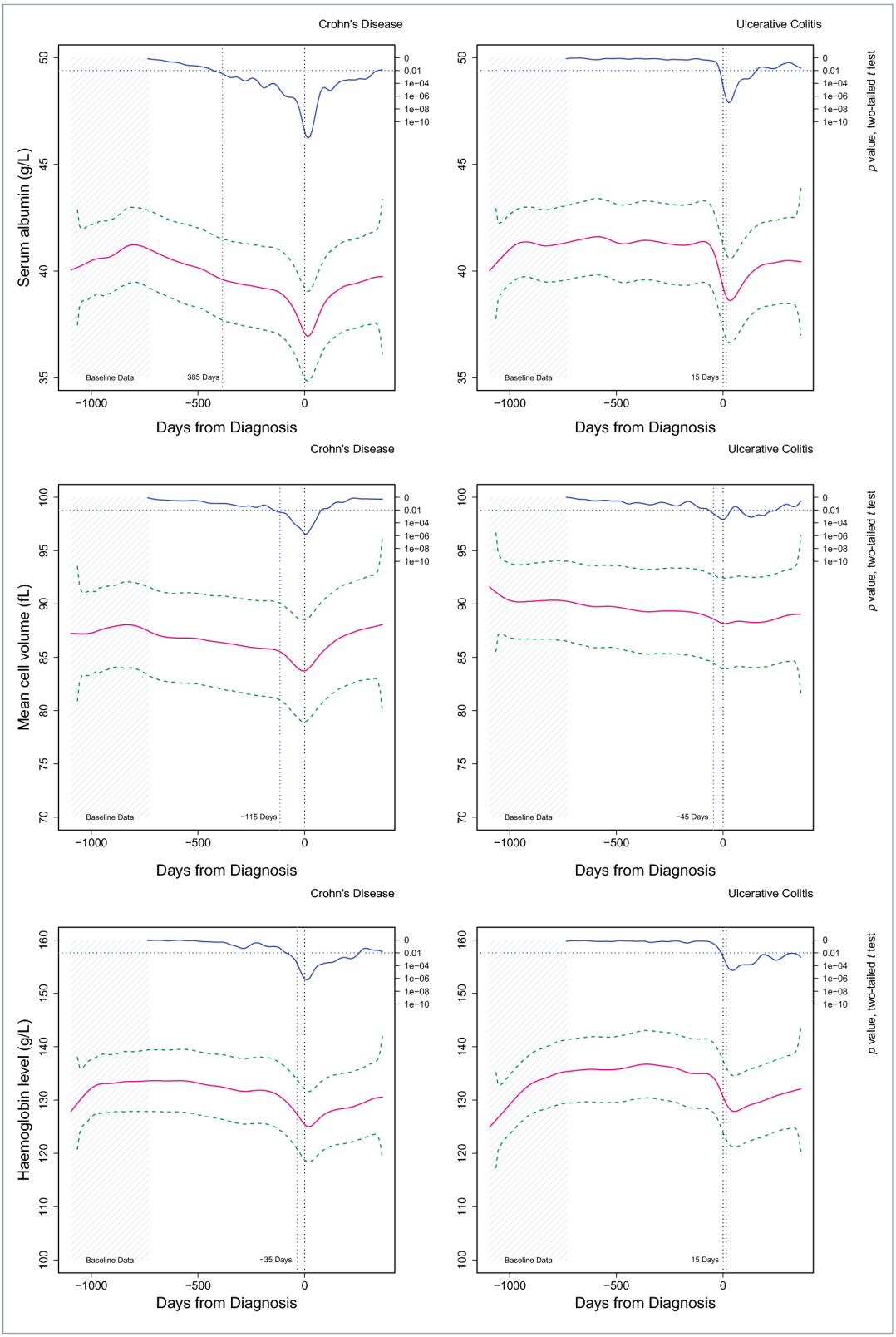
Collaboration with researchers from Brisbane and New Zealand led to a study where the culmination of thousands of blood tests over three years from participants with either Crohn's disease (CD) or ulcerative colitis (UC) led to the identification of a set of biomarkers that change significantly in the months prior to the diagnosis of disease.

The study showed that following patients' blood pathology tests in the 12 months prior to diagnosis, researchers were able to pinpoint the time at which each biomarker changed significantly away from normal, providing guidelines for future testing in the clinic.

Figure 1 shows the assessment of three biomarkers over time for CD and UC, and the point at which these biomarkers changed indicating their useful prognostic capability. The study was published in the Digestive Diseases and Sciences Journal in February 2019.

BIOSTATISTICS (CONTINUED)

Figure 1: Blood based biomarkers to predict IBD pathology.



INTERNATIONAL COLLABORATIONS

Further work in the blood based biomarkers space has attracted attention from world leading AD laboratories, with a major laboratory in the US run by Prof Randall Bateman collaborating to investigate their own blood based biomarkers to detect AD pathology. Results from Prof Bateman's study were presented at the 2019 Alzheimer's Association International Conference in Los Angeles, alongside data from two other large studies Biofinder and ADNI. This is definitely a space to watch for blood based biomarkers for AD.

COLLABORATORS:

- ADNeT team
- CRC in Cognition and its Disorders
- Australian Imaging Biomarkers and Lifestyle (AIBL) study
- Centre for Applied Statistics, University of Western Australia
- University of Melbourne
- Florey Institute of Neuroscience and Mental Health
- Nuclear Medicine and Centre for PET, Austin Health
- School of Medical and Health Sciences, Edith Cowan University
- Institute for Future Environments, QUT
- Brisbane Inflammatory Bowel Disease group
- International Inflammatory Bowel Disease Genetics Consortium
- MD Anderson Cancer Center
- Departments of Neurology, Harvard Medical School
- Maurice Wohl Institute for Clinical Neuroscience, Kings College London
- Institute of Health Informatics, University College London
- Biogen
- Abbvie
- Roche Diagnostics
- ADx-EUROIMMUN
- Nestle.

HIGHLIGHTS FOR 2018/19:

- Real bench-to-bedside research with biomarker studies leading to changes in clinical practice
- 17 published journal articles
- 17 conference presentations.

AIMS FOR 2019/20:

- Develop new statistical methods
- Pursue novel science projects
- Engage external collaborators
- Inclusion as chief investigators on successful grant bids with external collaborators
- Grow the team through employment of a post-doctoral scientist
- Answer pertinent research questions resulting in peer reviewed journal publications and conference presentations.

HEALTH SERVICES

2018/2019 SCIENCE AND IMPACT HIGHLIGHTS

- The Smarter Safer Homes project to support independent living recruited more than 50% of participants from three service providers from metro and regional Queensland.
- 100-Smart Home Testbed commenced on 25 homes in Brisbane to evaluate ADL and 25 homes in Geelong to test comfort.
- Commenced Indigenous community and organisation engagement on mobile health and Smart Home projects.
- Smarter Safer Homes' novel analytic of the objective measure of functional assessment was filed for an international patent.
- The Health Services group received recognition for their innovations, with three Queensland iAwards for Pain ROADMAP, two Victorian iAwards for CALD Assist, and an International Hospital Federation, Gold Excellence Award for the M♡THer platform.

Health Services Group Leader: Mohan Karunanithi

Mohanraj Karunanithi has a doctorate in Biomedical Engineering from the University of New South Wales. He has over 10 years of experience in cardiac research and five years' medical industries experience. At the Australian e-Health Research Centre, he manages and coordinates the Health Services Group undertaking research in translating services on screening, diagnosis, management and delivery of chronic diseases and aged care towards community care settings.

Mobile Health Systems Team Leader: Marlien Varnfield

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

Health Internet of Things Team Leader: Qing Zhang

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

Digital Health Engagement Team Leader: David Silvera/ Jill Freyne

For effective adoption of new health intervention delivery, particularly using technology, consumer/provider driven design is paramount. Our Digital Health Engagement team aims to provide closely aligned consumer/provider design and evaluation for new technology-based care delivery systems. The team is equipped with expertise across human-computer interaction, personalisation and recommendations, persuasive technology, socially assistive robotics, and neuroscience. The team designs technology-based interventions that can be used by clinicians to improve workflow and enhance service delivery, and by individuals to support them in playing an active role in their health management.

Australian Tele-health Research and Development Group Lead: Yogi Kanagasingam

The Australian Tele-health Research and Development Group is a partnership between the Western Australian Department of Health and the Western Australia node of the Australian e-Health Research Centre. The team, based in Perth, is centred on research that provides digital disease screening and diagnosis using telemedicine to enable healthcare accessible to rural and remote Australia. The team's main focus is the development of novel telemedicine technologies to deliver non-invasive ocular imaging techniques for chronic diseases such as diabetes, neuro-degenerative diseases (eg. Alzheimer's disease and stroke), burns and wound care management. The team was recognised in the WA Information Technology and Telecommunications Alliance (WAiTTA) Incite Awards 2018 – Winner of Most Innovative Enabler in Health Care, and Achiever of the Year.

MOBILE HEALTH SYSTEMS

Mobile health (mHealth) solutions, or healthcare that uses smartphones and other mobile devices, can enable real-time information exchange between patients and healthcare service providers. mHealth can provide support and timely interventions, and by engaging patients in managing their own health conditions it has the potential to move the balance of power from healthcare providers to healthcare users and reduce the healthcare burden.

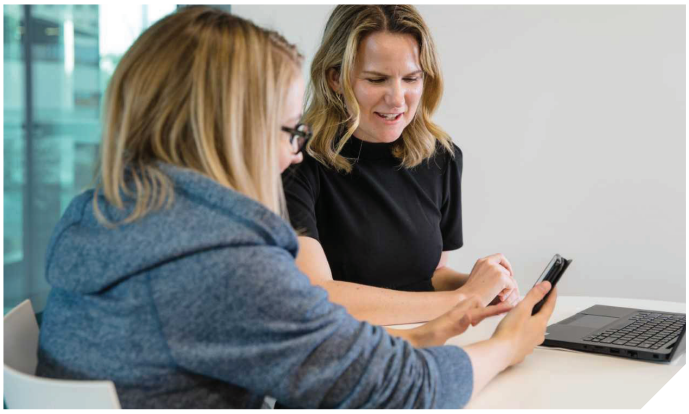
The Mobile Health Systems multidisciplinary team partners with clinicians and consumers to design, develop and evaluate patient online portals and mobile applications to improve coordinated care for a variety of chronic conditions. Recent work includes digital solutions to support the management of chronic pain, kidney disease, diabetes, lung disease and mental illness. The team is also involved in developing a wearable sensor system for early detection of cerebral palsy, by monitoring body movements of neonates.

PAIN ROADMAP: CHRONIC PAIN MANAGEMENT PILOT STUDY

The Pain ROADMAP pilot study began in 2018 and concluded in early 2019. Twenty participants with chronic pain completed an intervention, referred to as activity pacing, which involved rescheduling activities that might aggravate pain or previously required significant opioid medication to complete.

The results are extremely encouraging. After the third monitoring period, participants reported less pain, stress and anxiety, and increased physical activity. Most importantly, there was a 20% reduction in the equivalent opioid intake and five out of seven individuals had ceased *pro re nata* opioid medication. Two individuals went back to work, fulfilling a goal set before the trial. 100% of participants indicated that specific feedback provided by the clinician was worth going through the monitoring procedures, and all participants said they would recommend Pain ROADMAP to others. Researchers behind the Pain ROADMAP project were recently awarded a grant to adapt the technology for applications involving children with chronic pain.

Figure 1: Dr. Nicole Andrews from Metro North and Health services with a Pain ROADMAP participant, reviewing the collected data.



EARLY DETECTION OF CEREBRAL PALSY

Every year, about 27,000 Australian infants born preterm have a heightened risk of developmental delay or difficulties such as cerebral palsy. Early medical interventions can significantly increase their quality of life and lower their lifetime healthcare costs, but methods for early diagnosis are nascent, limited, and often case-specific.

In 2018/19, we began two studies to evaluate a wearable sensor system to support earlier diagnosis of cerebral palsy in both clinical and home environments. Infant wearable sensors can be used to measure and quantify extremity motor characteristics, indicative of normal or abnormal development. Under normal developmental trajectories, infant movements will be fluent and varied, representative of a healthy and developing brain. In cases where an injury or insult may be present in the brain, the movements are more patterned, repetitive, and monotonous. Unobtrusive sensors placed at the hands, feet, and head can measure motor characteristics and identify infants at risk of cerebral palsy for follow-up testing and referral to early intervention.

With novel 3D printing techniques, we can quickly fabricate different sensor cases to match sizing variations in babies, providing a customised fit for each infant at every age This method can quickly fabricate and trial sensor variations, such as retroreflective markers for outside biomechanical motion capture analysis.

Working with clinical partners at Child Health Queensland, The University of Queensland, and the Royal Brisbane and Women's Hospital, the studies have so far recruited 14 infants from healthy and high-risk cohorts and evaluated their movements using wearable sensors and clinical motor assessments. Studies are expected to conclude by mid-2020.

Figure 2: Three-month-old infant with sensors and retroreflective marker arrays placed at the hands, feet, and head.

INNOVATIVE MOBILE HEALTH PROGRAM FOR COPD

Chonic obstructive pulmonary disease (COPD) is a leading cause of mortality, morbidity and healthcare costs in our community and globally. To improve health outcomes, patients with COPD need to manage their health conditions through medicines, controlling symptoms, and modifying risk factors. Management is a core component in evidence-based clinical guidelines for COPD, but patient compliance with the management is often suboptimal.

We have developed MH-COPD, a mHealth-enhanced program to support disease management currently being evaluated in a randomised controlled trial at the Prince Charles Hospital. Patients can use the smartphone app at home to review educational videos, monitor COPD symptoms and risk factors, follow their action plan, and learn to use inhalers effectively.

Based on the MH-COPD study, a new research study was initiated to use an AI-based chatbot to help people quit smoking cigarettes, a leading risk factor of COPD. Although smoking cessation effectively prevents COPD progression, achieving this remains a clinical challenge. National approach of smoking cessation through Quitline is largely underused as smokers often concerned with invasion of their privacy. In contrast, our chatbot initiative would be intuitive and friendly to use, protect user privacy, reach a large population through social media apps and the web, and has the potential to improve user engagement and adherence via multimedia components.

Figure 3. The care model of the MH-COPD program includes the components of health education, electronic COPD action plan, symptom monitoring, physical activity, smoking cessation, and inhaler technique.

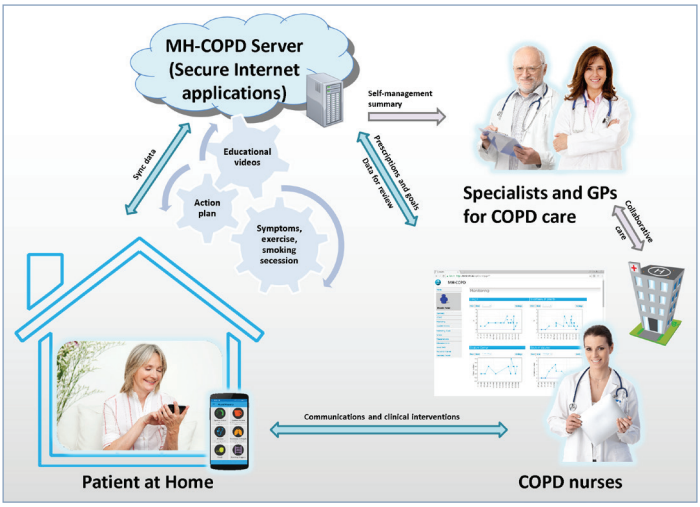


Figure 4. Left: The user interface of the MH-COPD app for users to manage symptoms, risk factors, and walking steps. Right: User interface of a prototype of the chatbot for smoking cessation.

PD-BUDDY: MOBILE HEALTH SYSTEM TO SUPPORT HOME-BASED PERITONEAL DIALYSIS

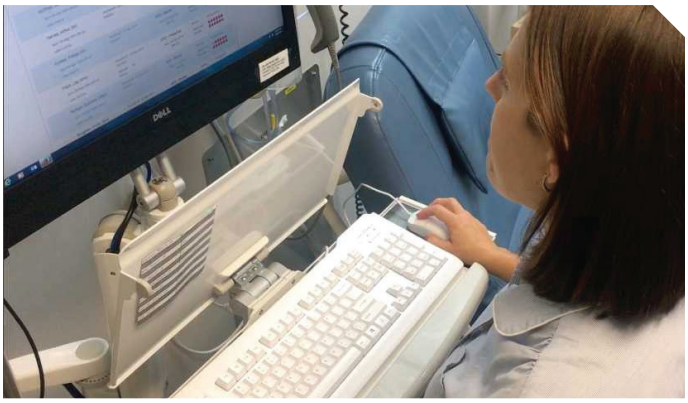
Chronic kidney disease (CKD) has been increasing at an alarming rate over the past two decades, as a result of the ageing population and the growing prevalence of diabetes, hypertension and obesity. In Australia, this is placing a significant burden on the healthcare system, with an estimated 1.7 million Australians aged 18 years and over presenting clinical evidence of CKD. Therefore, cost-effective healthcare that promotes patient empowerment, self-management and home treatment such as peritoneal dialysis (PD), is essential.

Developed in collaboration with Logan Hospital, Metro South Hospital and Health Service, PD-Buddy is a smartphone and internet-based interactive system that accompanies and guides peritoneal dialysis patients through every step of their dialysis treatment. The system allows for monitoring of patient health measures, provision of educational multimedia, and assistance in appointment scheduling. It also provides shared access to patients' multidisciplinary care teams.

The PD-Buddy solution was tested in a feasibility study at the Peritoneal Dialysis Unit at Logan Hospital from June 2017-July 2018. It was well received by patients and their clinicians; data from the PD-Buddy portal showed a very high usage of the app by patients, with the dialysis fluid exchange volumes the most commonly used feature, with an average 19-23 entries per month over six months. Blood pressure, body weight and blood glucose levels were also regularly entered. 100% of patients at the final survey strongly agreed the app was easy to use and fit in with their lifestyle, and would recommend it to others with kidney disease. 85% felt better supported by nursing staff. Clinically, episodes of peritonitis and exit site infections in patients with the app were lower than those without it.

Funding has been secured to continue the use of PD-Buddy at Logan hospital, while extending to a pilot study at the Princess Alexandra Hospital. PD-Buddy has been identified as a suitable solution to people undergoing haemodialysis, and has also been deemed suitable by nephrologists to manage their kidney transplant patients, signifying utilisation in national and international markets.

Figure 5: Ms Marnie Budd, Clinical Nurse, Peritoneal Dialysis Unit, Logan Hospital, viewing the progress of her patients through the clinician web-portal.



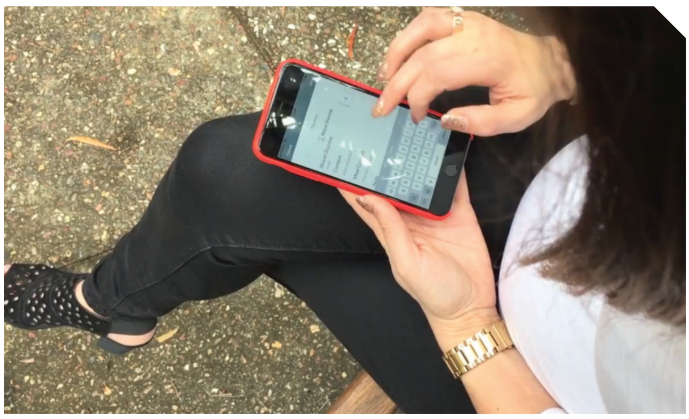
M♡THER: AN APP THAT HELPS CLINICIANS MONITOR PREGNANT WOMEN WITH DIABETES REMOTELY

Gestational diabetes mellitus (GDM) is an increasing problem among pregnant women worldwide, leading to snowballing healthcare costs. The condition has adverse effects on pregnancy outcomes and implications for the long term wellbeing of mother and infant, largely from uncontrolled blood glucose levels. Treatment controlling these levels can considerably reduce the risks, so we developed M♡THer, an interactive system designed to support women from diagnosis of GDM through to childbirth, and to improve multidisciplinary care co-ordination through sharing clinical information access.

M♡THer was tested in a feasibility study of 40 women (mean age 30 years old) at Redland Hospital from August 2017-April 2018. The app was well received by the women as an alternative to the paper-based BGL recordings, with all respondents agreeing the app was user-friendly, convenient, and helpful in managing their conditions and supporting their confidence in doing so. Treating clinicians reported improved communication with the women in their care and an increase in multi-disciplinary co-ordination. The platform enabled early intervention for a number of women identified with elevated blood glucose level readings in the first week of using the app.

Preparations are underway to conduct a multi-site implementation study at all Metro South Health prenatal clinics, and there is now the ability to offer the app to non-English speaking women. With more than 1000 women expected to be involved in the implementation study, we envisage providing the necessary evidence of delivering a new model of GDM service delivery without compromising healthcare.

Figure 6: Redland Hospital research participant entering data to the M♡THer app. Blood glucose level readings can be uploaded manually or via bluetooth.

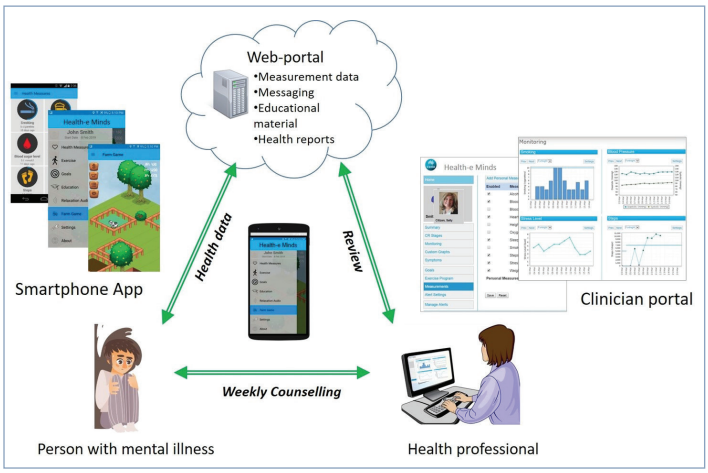


HEALTH-E MINDS

Serious mental illnesses (SMI) such as schizophrenia, bipolar disorders and depression have significant economic, social and individual costs worldwide. For people living with SMI, poor health behaviours and socioeconomic concerns contribute to poor health outcomes and reduced life expectancy. Data suggest that nationally, only about a quarter of the demand for SMI support services is met. Evidence suggests mHealth interventions are increasingly being adopted and valued by people living with SMI.

Our Health-e Minds study is evaluating a participatory personalised and gamified mHealth platform to support healthy behaviours for people with SMI, through a feasibility study at the Sunshine Coast University Hospital, Queensland (n=40). Primary outcomes are user adoption (patient and clinician usage and user satisfaction) and secondary outcomes include patient quality of life, depression and functional capacity. We believe that the solution will encourage and support healthy living behaviours for people with SMI.

Figure 7: The components of the Health-e Minds platform. Novel to the platform is a farm game component that rewards patients, using their measured activities (as measured by the app) against goals set in consultation with their clinician through the clinician portal.



MOBILE HEALTH SYSTEMS (CONTINUED)

CARDIAC REHABILITATION ACROSS CULTURES AND LANGUAGES

In 2014, we validated a mobile health home-care model for cardiac rehabilitation (CR), which used smartphones and the internet to deliver rehabilitation in the patient's home setting to align with their lifestyle. This platform was tested in a randomised clinical trial, becoming the first clinically validated mobile health delivery of CR, improving uptake, adherence, completion rates of participants and with similar health outcomes as that of the traditional centre-based CR programme.

To enable this new innovative CR delivery internationally and validate it irrespective of the intrinsic characteristics of the health structure and the culture and language of the users, we have reached out to undertake a pilot study in CR centres in four different countries in Europe (Sweden, Belgium, Netherlands and Poland). The results of this study would pave the way for a multi-centre randomised clinical trial with CR delivery sites in Europe. For this study we are utilising Cardihab (which was the spinout of CSIRO mobile health CR study) as commercial partner for delivering the cardiac rehab platform, which has been translated into Swedish, Dutch and Polish.

COLLABORATORS:

- Queensland Cerebral Palsy Rehabilitation and Research Centre
- University of Queensland
- Child Health Queensland
- CSIRO's Data61
- Royal Far West Hospital (Manly, NSW)
- Metro North Hospital and Health Service (The Prince Charles Hospital; Royal Brisbane and Women's Hospital)
- Metro South Hospital and Health Service (Redland, Logan and Beaudesert Hospitals)
- Sunshine Coast Hospital and Health Service (Sunshine Coast University Hospital).

Figure 8: Right: Dr Wendy Dutton and Susan Freiberg receiving the the International Hospital Federation, Gold Excellence Award.

Figure 9: Left: M♡THer team members from CSIRO and Metro South Health with the 2018 Award for Excellence presented by Steven Miles, Minister for Health and Minister for Ambulance Services.

Figure 10: Dr Nicole Andrew and Dr David Ireland receiving an iAward for Research & Development Project of the Year for the Pain ROADMAP project.

HIGHLIGHTS FOR 2018/19:

- The M♡THer platform won the Metro South Health Board Chair's Award "Innovation Through Digital Technology" in Brisbane, Sep 2018; the International Hospital Federation, Gold Excellence Award "Quality & Safety and Patient Centred Care" in Brisbane, Oct 2018; and was awarded "Highly Recommended" at the Queensland Health Awards of Excellence, Dec 2018.
- The Pain ROADMAP project was effective in reducing opioid medication in patients with chronic pain. The solution won one Queensland iAward 2019 and also two merit awards for R&D Project of the Year and Community Markets respectively.

AIMS FOR 2019/20:

- Develop new features to the ROADMAP solution including machine learning and gamification components to increase the data accuracy and appeal to younger users
- Commence multi-site M♡THer implementation study at all Metro South Health prenatal clinics
- Conduct PD-Buddy pilot studies at Princess Alexandra Hospital (QLD) and Nepean Health (NSW)
- Complete the Health-e Minds feasibility study at Gold Coast University Hospital
- Extend the digital health platform to the areas of dementia, cancer and palliative care
- Complete IGMS study 1 on healthy term infants, substantial recruitment for IGMS study 2
- Secure extensive external funding such as NHMRC, Cerebral Palsy Foundation, Advance Queensland, CRC Northern Australia
- Collaboration with QAIHC (Queensland Aboriginal and Islander Health Council) to engage and establish potential trial sites in an Aboriginal and Islander Community Controlled Health Organisation (AICCHO) in Queensland for the M♡THer mHealth platform.

STUDENT HIGHLIGHT

PhD student Nazli Ghafouryan

Project title: A mobile-based multidisciplinary virtual clinic for patients with Acute Coronary Syndromes: a randomised controlled trial, MoTER-ACS project

The aim of this research was to develop a smartphone-based multidisciplinary intervention for supporting patients with Acute Coronary Syndrome (ACS) and to test the feasibility of the intervention in a pilot randomised controlled trial. To develop MoTER-ACS intervention, we conducted small studies known as pre-study surveys including short structured interviews with small groups of patients (N=30), one session of focus group (N=10) with healthcare professionals, and a survey with cardiologists (N=30). The project received the Experienced Researcher Grant from The Prince Charles Hospital (TPCH) Foundation to cover the pilot study costs and expenses. The smartphone-based intervention was developed based on the results of the pre-study survey and the MoTER-ACS platform customised accordingly. The intervention consists of secondary prevention components to address ACS management and to deliver education on nutrition and healthy eating; risk factors monitoring such as blood pressure, weight, diabetes, and smoking; and psychosocial support from clinicians.

The post-discharge smartphone-based program will be offered to patients as an alternative program to a hospital-based follow-up. The smartphone app covers complete multimedia educational materials required to adopt a healthy lifestyle for patients with ACS and consists of user-friendly tools to assist patients to self-manage their condition by daily monitoring of health data and physical activity. Using the clinical portal, clinicians can regularly access patients' health data and provide continuous guidance and support. The study protocol was written for pilot testing of the intervention including a sample of 54 patients and follow-up period of 12 weeks, and the trial registered in Australia and New Zealand clinical trial registry (Trial Registration number: ACTRN12619000059167). However, due to the post-discharge outpatient clinic in TPCH being terminated as a service, recruitment of ACS patients did not proceed. Recently, we received support from TPCH Foundation to customise and conduct the pilot study in a heart failure service unit at TPCH. We are now working with TPCH governance unit to obtain variation on the study agreement and to finalise ethical amendment.

MOBILE HEALTH SYSTEMS (CONTINUED)

Figure 11. MoTER-ACS platform.

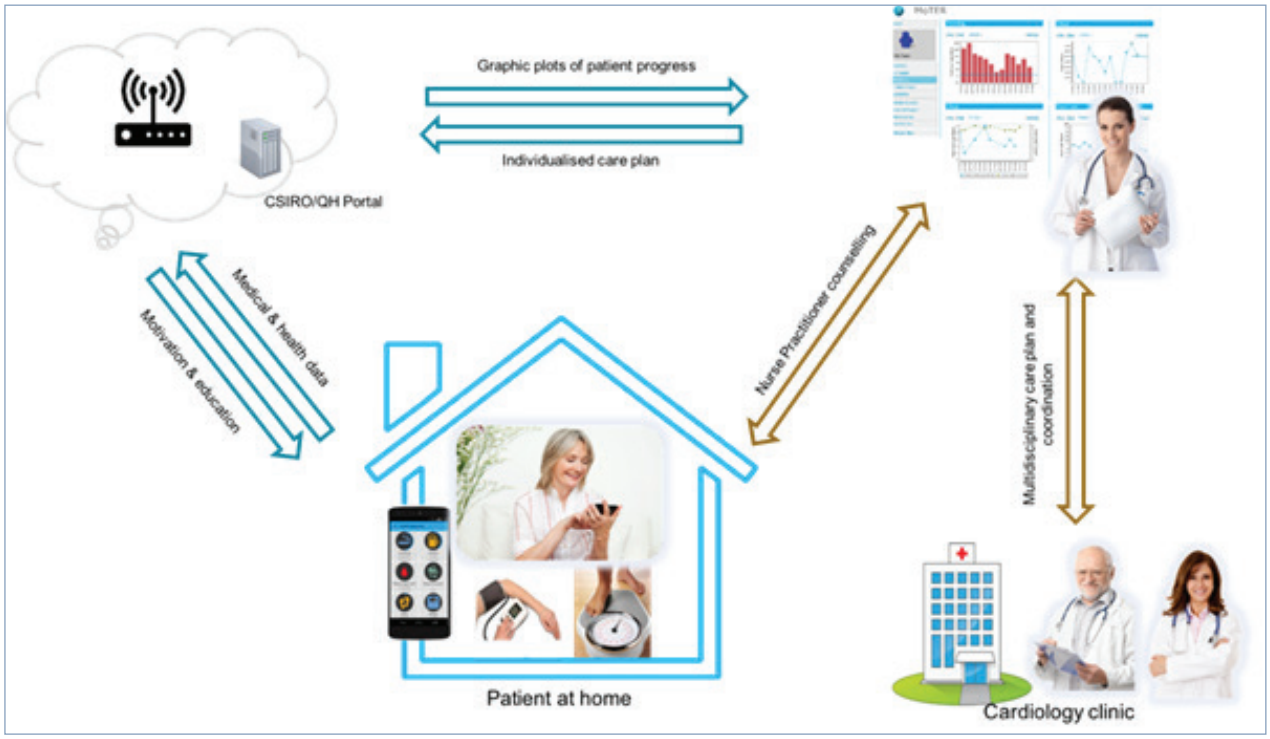
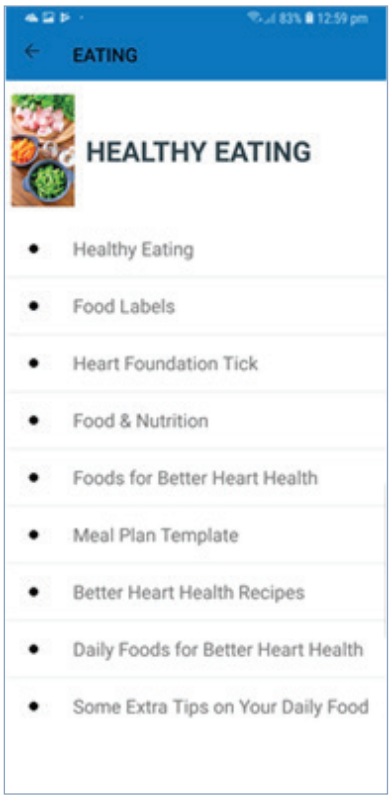
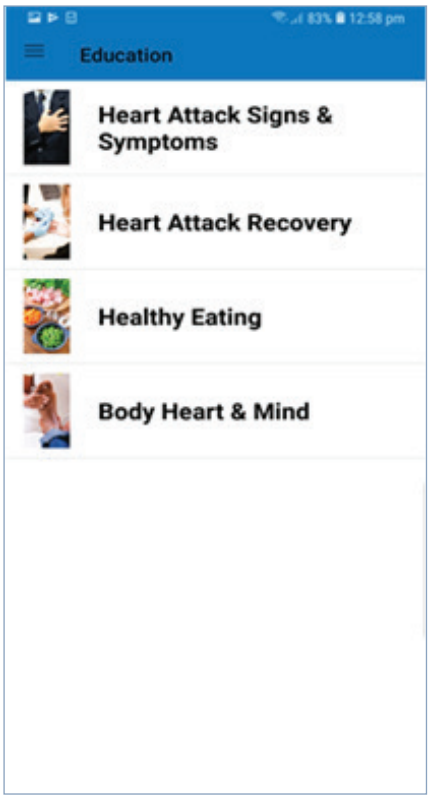


Figure 12. Selected screenshots showing educational materials.





HEALTH INTERNET OF THINGS

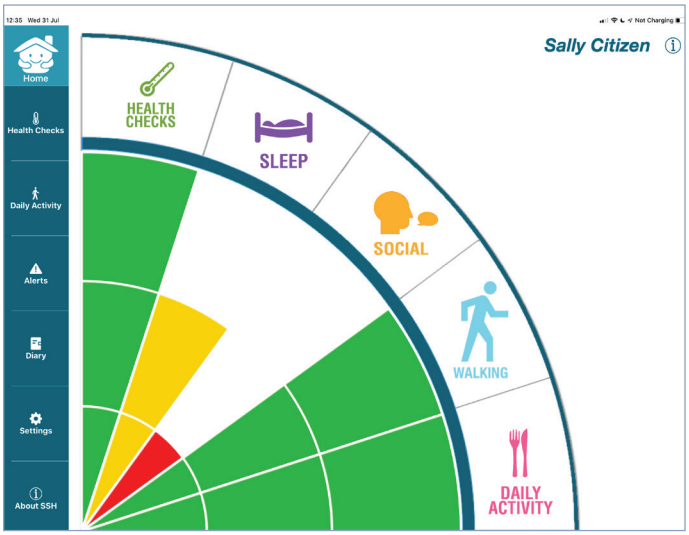
The Internet of Things (IoT) refers to a network of internet-connected devices that collect and transmit data through embedded sensors. The Health Internet of Things team uses IoT to research and develop solutions for health and aged care.

SMARTER SAFER HOMES (SSH) FOR AGED CARE

Our Smarter Safer Homes (SSH) lifestyle-based technology platform was developed to enable older people to live longer in their own homes, designed with consumers to enable self-management, and engage assistance from informal and family carers and clinical services. It features an individualised measure of functional independence, together with assessments of health and social isolation, from an unobtrusive, sensor-enabled home.

Our AEHRC-led SSH platform project is a multidisciplinary collaboration with universities, aged care service providers and local clinicians. It uses cutting edge pervasive communication and wireless sensor and monitoring technology, and features a novel metric to determine personalised functional independence, indexed through the "Objective Activity of Daily Living". The potential benefits of these technologies are wide, including engagement of families and services at a distance, to provide timely and on-demand care and substantially reducing costs to older persons and health and aged care services.

Figure 1: SSH mobile application allows residents to view data derived from the sensors and medical devices.



SSH FOR SUSTAINABLE, COST-EFFECTIVE AND SMART ASSISTED INDEPENDENT LIVING FOR DEMENTIA AND AGED CARE SERVICES

This project aims to use the Smarter Safer Homes platform to revolutionise aged care services delivered to people in their homes, in alignment with consumer directed care, through:

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

To achieve this, SSH will be implemented in metro and regional areas among sites serviced by three aged care providers that present different geographical challenges and workforce issues. We will use SSH to evaluate the impact of community care for older people, through a randomised controlled trial of 200 participants (65 years and over, living at home, and supported by home care service providers). In the past year, this project has been granted ethics approval, and has established governance committees to oversee project progress, such as Risk and Safety and an international expert reference group. Ninety participants have been recruited in the Sunshine Coast, Brisbane and Toowoomba regions of Queensland in collaboration with service providers Anglicare Australia, integratedliving Australia Ltd, and All About Living. SSH has been deployed to 30 participants in the intervention group.

In the next 12 months, we aim to complete recruitment for 200 homes, complete a 6-month assessment for all participants, undertake 12 months for more than half the participants, and publish the study protocol in an ageing journal.

SMARTER SAFER HOMES 100 TESTBED

This project's objective is to deploy 100 Smarter Safer Homes platforms within Australia to provide an ongoing testbed for AEHRC research. Through this project, and in collaboration with integratedliving Australia Ltd and Geelong Sustainability, we aim to collect longitudinal sensor and activity data from real residential homes, and to construct a database to continuously develop, evaluate and extend the SSH platform (installation of inconspicuous sensors and devices to monitor the activities of daily living of seniors). We also aim to foster collaborations with service providers on a well-developed research platform with continuous inputs of large quantity of real data to help shape an economic and sustainable care delivery system that can affect policy-makers and eventually benefit all Australians.

Over the past year, we received ethics approval for a 25-home trial at the Brisbane testbed and deployed SSH for 12 participants here. Ethics approval was also granted for another 25-home trial at Geelong, Victoria, to observe thermal comfort in seniors via SSH activities of daily living metrics. In 2018-19 we aim to complete recruitment for 25 homes at both the Brisbane and Geelong testbeds, and commence installation at the Geelong testbed.

HEALTH INTERNET OF THINGS (CONTINUED)

PROSPECTIVE IMAGING STUDY OF AGEING: EARLY DETECTION OF DEMENTIA BY SMART SENSING

Through a collaboration with QIMR Berghofer Medical Research Institute, the University of Queensland and the University of Western Australia, this project aims to elucidate neurobiological, psychological and physiological changes at a very early stage of dementia, which includes uncovering genetic and lifestyle risk factors for dementia, and establishing a preclinical AD cohort based on biological markers. Our focus is to monitor changes in sleep patterns across the spectrum of the disease via smart sensing technology. The lifestyle stream aims to collect longitudinal sleep sensor data from healthy older adults and participants who are living with dementia, monitor changes in their sleep patterns, and investigate the features extracted from sleep that can act as an indicator of cognitive decline.

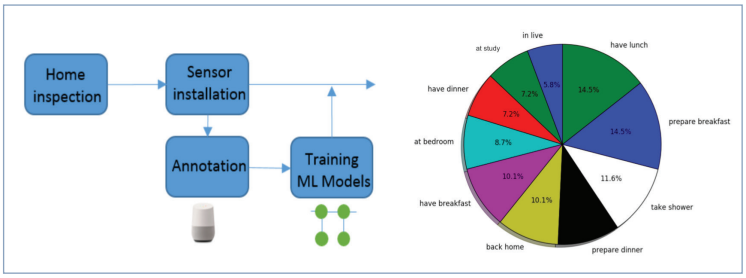
Figure 2: Prospective Imaging Study of Ageing.

In the past year, 76 participants were recruited to monitor their sleep patterns for around 5 months. Research protocol was developed for an open label trial at The Prince Charles Hospital (TPCH) sleep lab to validate the sleep sensor measurements, and an ethics application submitted to TPCH ethics. In the next year we aim to complete the participant recruitment for the PISA lifestyle stream, undertake PISA data analysis using data from other streams, i.e., neuroimaging, neuropsychology, and genetics, and conduct an additional trial in TPCH sleep disorders centre to validate the sleep sensor measurements.

SMART HOME MULTI-RESIDENT ACTIVITY RECOGNITION

The multi-resident activity recognition system (MARS) is designed to support multiple occupants in a smart home with minimum impact on their lifestyles. The system uses Google Home and natural language processing to annotate and label activities, then adopts deep learning techniques to capture and predict activities. We evaluated the system in the house of a family of three, receiving the best state-of-the-art results in activity recognition accuracy.

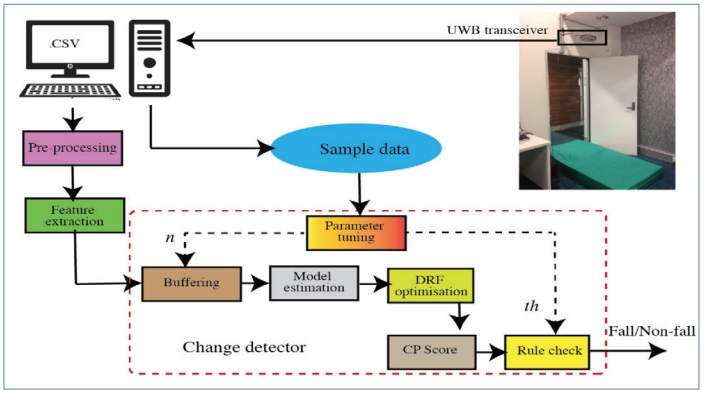
Figure 3: The MARS system and most labelled activities through voice recognition and natural language processing (these are real inputs from residents).



FALL DETECTION IN SMART HOMES USING A NON-WEARABLE RADAR SENSOR

Falls are a major issue endangering the lives of older adults. Numerous research studies investigate the use of wearable technologies to detect falls in everyday environments. Although wearable sensor solutions provide good accuracy and sensitivity for fall detection, it may not always be convenient or desirable for older adults to wear a tag or sensor in home environments. This project discusses using non-wearable ultra-wideband (UWB) radar sensors as a practical, environmental fall detection solution in home settings.

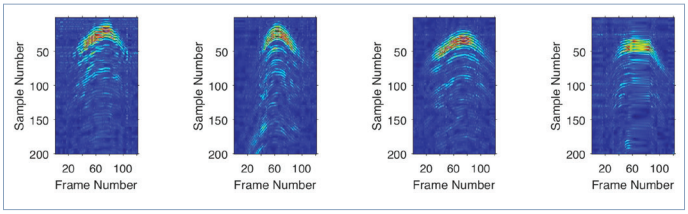
Figure 4: The unsupervised fall detection system.



ID SENSOR FOR HUMAN IDENTIFICATION

This project achieves the goal of human identification through properly processing and analysing the received signals from the UWB radar installed in indoor environments. We employed unsupervised feature learning techniques to automatically learn local, discriminative features that can incorporate intra-class variations of the same identity, and yet reflect differences in distinguishing different human identities.

Figure 5: Scattered UWB signals of various people with individual walking styles.



IMMERSIVE AUGMENTED REALITY: REMOTE CLINICAL CONSULTATION

Using emerging augmented reality (AR) technologies on mobile devices, this project developed an AR clinical consultation system through an iPad and a Kinect sensor. This low-cost and highly portable AR consultation system can be easily deployed in a patient's home and clinician's office with minimum impact on their normal daily activities. While it provides immersive telehealth consultation experience for patients, it can also help clinicians to better explain complex medical conditions to patients through visualisation and simulation. Collaborators on this project include CSIRO's Energy business unit, aged care service providers, QIMR Berghofer Medical Research Institute, Wuhan University Stomatological Hospital, Oregon Health & Science University, Washington State University, University of Twente in the Netherlands, and Shanxi University, China.

Figure 6: AR Doctor system structure.

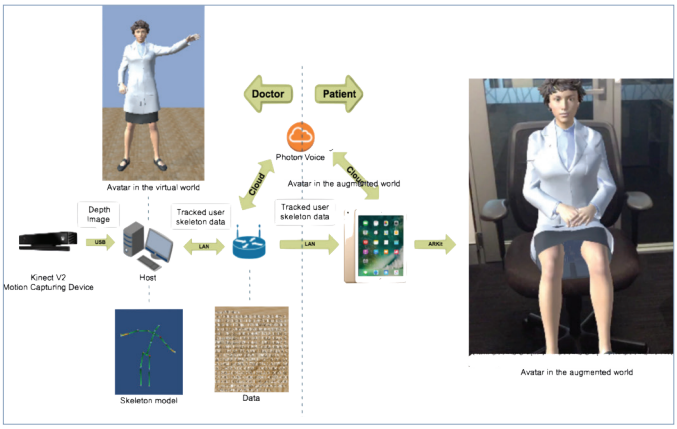


Figure 7: The AI dental research collaboration with Wuhan University Stomatological Hospital.

HEALTH INTERNET OF THINGS (CONTINUED)

COLLABORATORS

- Anglicare Australia
- integratedliving Australia Ltd
- All About Living
- Geelong Sustainability
- CSIRO's Energy business unit
- Aged care service providers
- QIMR Berghofer Medical Research Institute
- Wuhan University Stomatological Hospital
- Oregon Health & Science University
- Washington State University, USA
- University of Twente, Netherlands
- Shanxi University, China
- QIMR Berghofer Medical Research Institute
- The University of Queensland (UQ)
- The University of Western Australia (UWA).

HIGHLIGHTS FOR 2018/19:

- Commencement of a 200-home randomised controlled trial at Queensland, supported by the Department of Health.
- Commencement of a 25-home longitudinal testbed trial at Brisbane.
- Evaluation of a novel ID sensor prototype.
- Signing of a Memorandum of Understanding (MOU) with Shanxi University on smart home sensor development.
- Commencement of a research collaboration with Wuhan University Stomatological Hospital on AI Dental research.

AIMS FOR 2019/20:

- Conduct a 200-home randomised controlled trial with aged care service providers at Queensland.
- Conduct two testbed trials in Brisbane and Geelong.
- Conduct a smart sensor trial in the PISA study.
- Submit patent application of the novel ID sensor.
- Evaluate smart home system with international collaborators at US and Europe.

DIGITAL HEALTH ENGAGEMENT

The Digital Health Engagement team draws on expertise across human-computer interaction, personalisation and recommendations, social robotics, persuasive technology and neuroscience to be a leading team in the design and evaluation of technologies to facilitate the provision of equitable health care.

The team designs technology applications that can be used by clinicians to improve workflow and enhance service delivery, and by individuals to support them in playing an active role in their health management to meet short- or long-term health and lifestyle goals. The team has a strong collaborative approach, leading and contributing to projects across AEHRC and several other CSIRO divisions.

WORKING WITH THE AUTISM COMMUNITY

For people on the autism spectrum, social interaction and communication can be significant challenges. Together with the wider autism community, we have been working in a number of areas to understand the roles that innovative technology can play during successive stages of childhood development in the home, in the classroom, and during extracurricular activities.

Socially assistive robots in education

We have developed interactive modules to support education for children with autism and intellectual disability. In collaboration with Murray Bridge High School, we have presented one of the longest studies to date of socially assistive robots as tools to assist in the education of secondary students diagnosed with intellectual disability and/or autism spectrum disorder.

Over a 24-month period, the robots NAO and PARO were used to support teaching at Murray Bridge High School's Inclusive Education Centre. The robots enriched the learning experiences of students, becoming rewarding social partners, and facilitating intrinsic interest through various levels of social communication and interaction.

To support our trials, we have developed an app and compatible user interface platform to control the social robots, facilitating the translation of research into practice.

Socially assistive robots in therapeutic intervention

In collaboration with the University of New South Wales, we are exploring the impact of social robots in therapy. In this project we demonstrate that a humanoid robot, KASPAR (developed at the University of Hertfordshire), can be used to facilitate therapy intervention within an Applied Behavioural Analysis (ABA) framework, supporting the acquisition of social interaction and communication skills of children on the autism spectrum.

The intervention in this study was guided by Social Stories, a tool to help individuals on the autism spectrum better understand the nuances of interpersonal communication and interact in an effective and appropriate manner.

Overall, our results demonstrate that the framing of the robot as a facilitating object during therapy, supported by Social Stories, can provide an environment where new skills can be introduced and practiced with the therapist as a mediator.

Figure 1. KASPAR interacting with a child while controlled by a researcher.

Robot learning behaviours from videos

The full potential of computer autonomy in socially assistive robotics in therapy and education is yet to be explored. In collaboration with the University of New South Wales, this project seeks to tackle some of the current technical barriers by using machine learning to constitute a "smart" robot. We developed a closed-loop behaviour planning system that enables a robot to learn co-speech behaviours from human speech videos in the autism and education context. Pilot user studies show promising results as compared to randomly selected pre-programmed behaviours.

Do children perceive robots as social agents?

Individuals on the autism spectrum typically have impairments in social understanding and social interaction. One theory posits that these impairments are the result of impaired Theory of Mind. Considering that individuals on the autism spectrum show social behaviours in response to social robots, we decided to measure their Theory of Mind abilities in response to social robots.

In collaboration with the University of Western Australia, we have developed an experimental paradigm based on the Frith-Happe Animations, silent animations that show two triangles moving in a variety of ways to depict different interactions. We translated these animations to videos of two humanoid robots (NAO) moving. This work aims to create a valid and reliable experimental paradigm to investigate whether autistic children have similar Theory of Mind abilities as neurotypical children in response to social robots.

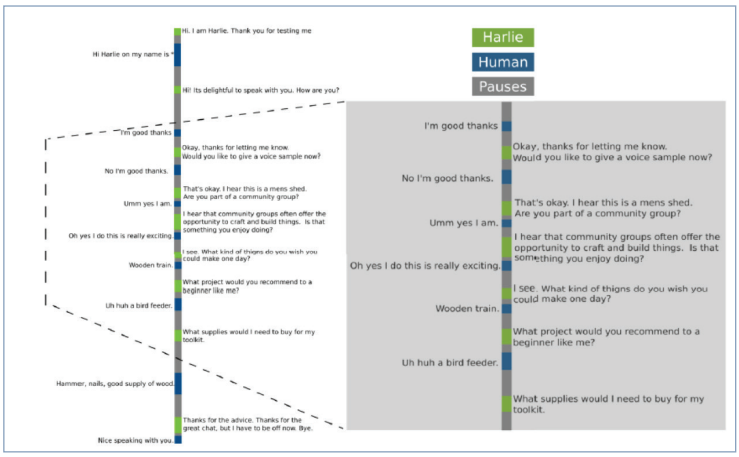
Figure 2. Stills taken from the Social Robot video scripted as 'Coaxing'.

DIGITAL HEALTH ENGAGEMENT (CONTINUED)

‘Hear’ to help: striving for greater participation and wellbeing through tailored chat-bot technology

For several years the development of an artificially intelligent, chat-bot technology has been underway. Similar to Apple’s Siri and Amazon’s Alexa, the chat-bot technology Harlie is being developed to support people with difficulties in speech, language and social interaction. In collaboration with Curtin University, Autism Academy for Software Quality Assurance (AASQA), the Queensland Department of Education and Training, and Autism Spectrum Australia, this project is working with people on the autism spectrum to determine how chat-bot technology can support education participation and education-related health and wellbeing (such as study-related stress or looking after yourself on campus).

Figure 3: A sample dialogue between Harlie and a person with autism. Green rectangles designate dialog generated from Harlie, blue rectangles designate responses from the user, grey rectangles indicate pauses in the timeline.



EMERGING TECHNOLOGIES FOR PRECISION HEALTH

The CSIRO Precision Health Future Science Platform is looking beyond precision medicine to incorporate other factors such as lifestyle and psychosocial factors. Particular interests are in continuous monitoring of individuals’ day-to-day lifestyle, physiological information and psychological factors, and their changes. Acquisition of largescale data is becoming more feasible with the introduction of smartphones, wearables, health sensors, smart home devices and other emerging technologies.

The Australian e-Health Research Centre is leading the development of a customisable large-scale data collection platform for precision health research, identifying the data to be captured and how the data can be used in a meaningful way. Using pregnancy as a case study, we are developing a Precision Health Pregnancy Care platform to support predictive analytics to facilitate early identification of risk factors that correlate with pregnancy-related conditions. We are engaging with clinicians at health services in Queensland to carrying out a user needs study to guide the technology design.

UNDERSTANDING THE EMERGING MEDICAL DEVICES LANDSCAPE AND THE ASSOCIATED REGULATORY ENVIRONMENT

Digital technologies are providing the foundation for many emerging global healthcare innovations. The Australian healthcare sector has been quick to develop and adopt these for cost-effective outcomes benefiting clinicians, patients and carers. To provide a sustainable and competitive environment for this to thrive, consideration must be given on how to cultivate a health technology ecosystem which allows developers to harness both clinical and technical expertise while maintaining a clear focus on safety and quality.

The Therapeutic Goods Administration (TGA) engaged CSIRO to conduct research to build an understanding of Australia’s Software as a Medical Device innovation, and to learn how and when agencies such as the TGA can support them in demonstrating the safety of their products on the global market. Working with the CSIRO Futures team, we conducted research into medical device cyber security to support the development of a TGA guidance document. This will assist the medical devices ecosystem to implement best-practice approaches to cyber security.

ACTIVATE TKR: MOBILE SUPPORT FOR ORTHOPAEDIC REHABILITATION

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

To evaluate the technology platform, a randomised control trial has been underway since November 2016. It is being conducted in a number of states in Australia, with about 150 patients undergoing TKR surgery. The trial is running for a period of 13 months for each patient. Over the past 12 months we have finalised recruitment with some patients now finishing their 13 month trial, and expect to finalise the trial this coming year.

CALD ASSIST: TRANSLATION SUPPORT EXPANDED FOR NURSING WORKFORCE

When clinical staff are unable to communicate directly with patients, their ability to adequately assess and respond to patient needs in a timely manner has the potential to affect patient care and experience.

In collaboration with Western Health, we developed the CALD Assist app, which translates key phrases into 10 common languages (in addition to English) using pictorial, video, written and voice-over prompts to ensure appropriate and timely care for inpatients. Further to the development of CALD Assist - Allied Health in 2014-15, we have expanded and evaluated CALD Assist to meet the specific needs of the nursing workforce. This app is available to download in the Apple App Store. This project was awarded with two iAwards in 2018.

COLLABORATORS

- Johnson and Johnson Medical AU
- The Project Factory
- Melbourne Genomics Health Alliance
- Western Health
- Autism Spectrum Australia
- Autism Hub
- Autism CRC
- Curtin University
- University of New South Wales
- University of Western Australia
- Murray Bridge High School
- Therapeutic Goods Administration, Department of Health.

HIGHLIGHTS FOR 2018/19:

- Finalised long-term trial with socially assistive robots in education.
- Finalised small trial with socially assistive robots in therapy.
- Finalised CALD Assist Nursing trial.
- Finalised recruitment for the TKR project.
- Held a co-design, focus group study on the chat-bot with students who are on the autism spectrum.
- Held a chat-bot building workshop with students who are on the autism spectrum.
- Finalised insight into current and emerging state-of-the-art sensing technologies for health and wellbeing.
- Finalised Software as a Medical Device Engagement Strategy.

AIMS FOR 2019/20:

- Finalise clinical trial for Activate TKR program.
- Provide additional evidence for the use of robots in educational settings.
- Develop and deploy chat-bot technology to facilitate participation in tertiary education and offer bullying strategies for children on the autism spectrum.
- Scope and prepare for trial a precision health platform for pregnancy care.

STUDENT HIGHLIGHTS

Yi Xiao joined CSIRO as a vacation student from the University of New South Wales. Yi is now doing her Bachelor of Honours research project on a behaviour planning system that enables social robots to learn co-speech behaviours from human speech videos.

Ziggy O'Reilly, a Psychology student from the University of Western Australia, as part of her Masters' project is investigating whether autistic children have similar Theory of Mind abilities as neurotypical children in response to socially-assistive robots.

Saminda Sundeepa, a PhD student from the University of Technology, Queensland, is working on affordable virtual companions to support social interaction and reduce subjective loneliness in children and adolescents with autism.

INDIGENOUS HEALTH SERVICES

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

The expansion of new technology platforms and mobile devices and improvements in wireless connectivity in remote areas has brought new opportunities for self-management and remote monitoring of health measures and medication. Despite recent advancements in reducing cardiovascular disease (CVD) mortality rates in Australia, the disease still accounts for a quarter of the difference in life expectancy between Aboriginal and Torres Strait Islander people and non-Indigenous people. Maximising the potential for mHealth solutions to assist and support the identification and management of CVD and other chronic diseases (including associated risk factors) faced by Aboriginal and Torres Strait Islander people is a critical challenge for AEHRC.

MHEALTH SCOPING PROJECT FOR ABORIGINAL AND ISLANDER COMMUNITY CONTROLLED HEALTH ORGANISATIONS

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

Queensland Aboriginal and Islander Health Council (QAIHC) is the peak body in Queensland representing 26 AICCHOs across the state. We have partnered with QAIHC to conduct a scoping study about how mHealth may add value to the screening and management of hypertension for Aboriginal and Torres Strait Islander people. This project is funded through the CSIRO Health and Biosecurity Indigenous Opportunities.

AEHRC Scientists and QAIHC staff visited AICCHOs located in Hervey Bay (Galangoor Duwalami), Mareeba (Mulungu), Cairns (Wuchopperen) and Mornington Island (Gidgee Healing) in April-June 2019. These project scoping meetings with AICCHO staff and representatives provided valuable opportunities to demonstrate the potential technology and learn more about what AICCHOs in QLD would like to see in an mHealth platform for the management of chronic disease and cardiovascular risk factors within their existing model of care. Findings of the scoping study indicate high levels of support for developing a digital platform that incorporates the feedback received from AICCHOs. Scoping study findings will inform potential funding opportunities for CSIRO and QAIHC to develop the mHealth digital platform. A Master of Philosophy student who is Aboriginal was accepted to commence at UQ School of Public Health in July 2019 to explore perceptions about the use of technology (including smartphones and devices (mobile Health)) for the management of risk factors for people with cardiovascular disease.

Over the next year, we aim to identify internal and external funding sources to progress findings from the scoping project, establish trial site(s) in an AICCHO, and co-design and co-develop an mHealth platform integrated with the existing AICCHO models of care.

Figure 1: Roderick Wright, Ann Woolcock, Stevan Ober, Ray Mahoney, Manuel Gonzalez-Garcia, Kelly Dingli at Galangoor Duwalami (Hervey Bay clinic).

Figure 2: Jason Leon, Wyomie Roberston, Kelly Dingli, Gail Wason, Ray Mahoney, Roderick Wright, Manuel Gonzalez-Garcia at Mulungu (Mareeba clinic).

SMARTER SAFER HOMES SCOPING PROJECT WITH WINNAM

Winnam Aboriginal and Torres Strait Islander Corporation is a 100 per cent community-based and controlled not-for-profit corporation that is a holistic service provider for the Aboriginal and Torres Strait Islander community in the Wynnum and Bayside Suburbs of Brisbane. These are within the boundaries of the Quandamooka country where the pandanus palm once grew in abundance. Winnam takes its name from the Aboriginal word for pandanus palm.

It uses all its income to extend or improve services for local Aboriginal and Torres Strait Islander people. Winnam was incorporated in 1990 by local Aboriginal and Torres Strait Islander volunteers and now has approximately 40 properties in the local Bayside area that are used to shelter vulnerable Aboriginal and Torres Strait Islander people. Winnam Aboriginal and Torres Strait Islander Corporation also owns and operates (with government funding assistance) the Georgina Margaret Davidson Thompson Hostel (known as Georgina Hostel) in Morningside.

AEHRC's Smarter Safer Homes (SSH) platform takes advantage of the latest wireless communication technologies in home and health monitoring sensors, to provide a smart home with consumer design interfaces and engagement

of informal (eg. family) support. This platform aggregates information from wireless sensors placed in a person's living environment to infer an individual profile of functional status to enable support from family members and/or carers.

We have partnered with Winnam Aboriginal and Torres Strait Islander Corporation to conduct a scoping study to gain an understanding of Aboriginal and Torres Strait Islander people's perceptions around home monitoring, and identify potential culturally appropriate modifications required for the SSH platform use in individual homes and in an aged care facility. This scoping project is funded by under CSIRO's Health and Biosecurity Indigenous Opportunities, and we have agreed and established a working partnership between AEHRC and Winnam Aboriginal and Torres Strait Islander Corporation to co-design and co-develop the scoping project.

Over the next year, we aim to conduct meetings with Winnam Aboriginal and Torres Strait Islander Corporation members and residents and with staff at Georgina Margaret Davidson Thompson Hostel in Morningside; to determine the viability of conducting a trial of SSH in partnership with Winnam Aboriginal and Torres Strait Islander Corporation; and to identify potential internal and external funding sources.

PRIMARY CARE DATA QUALITY FOUNDATIONS PROJECT

The Primary Care Data Quality Foundations project is a community-driven consensus programme funded by the Department of Health and led by AEHRC, standardising primary care data using a standard data model (FHIR) and a terminology (SNOMED CT) to improve data quality, interoperability and population health data use. The next phase of the programme is expanding to include the data requirements for recording social determinants of health, risk factors and information on family history. This project will explore how this data could be used to support health assessments such as the RACGP National Guide to a Preventative Health Assessment and the Medicare Health Assessment for Aboriginal and Torres Strait Islander People (MBS ITEM 715).

WORKING WITH AURUKUN: CONVERSATIONS ON COMMUNITY HEALTH AND WELLBEING

The Aurukun Community brings together five ritual clan groups, four of whom are separated from country by the Watson and Archer river system, necessitating long transits to be on country. The Community has a strong desire to boost their ranger services through connection to country and Indigenous-led enterprise development, and has been working with CSIRO Land & Water (L&W) for some time on successful country projects including feral pig management and sea turtle preservation, particularly through the APN (Aak Puul Ngantam, which translates as 'Our father's father's country').

The APN work, in partnership with the Wik Prescribed Body Corporate, Ngan Aak Kunch, and project partners, is to help families return to their traditional land in a meaningful way. AEHRC was invited to the Community to discuss ways to enhance wellbeing, particularly for older and younger Community members less able to access country.

The Community has a number of strengths that could be utilised for a project promoting health and wellbeing including strong practices for sharing traditional knowledge, products from previous projects and existing programs. One such program, the 'Returning Generation' school camp, is hosted by APN Rangers Services, and designed to provide an opportunity for Year 6 students to learn from selected elders and rangers about how to care for their country along with undertaking traditional activities.

Prior to visiting the Community, AEHRC, in collaboration with CSIRO Energy, developed videos of traditional lands augmented with frog and bird call audio obtained from drone footage and recordings by L&W. A number of virtual reality resources were also collected, including footage of Elders on Country in Bidyadanga, WA, developed by PHORIA, Victoria, and provided with permission by the people of Bidyadanga. We met with the Principal of Aurukun State School, where L&W have a resident scientist, and discussions were held around digital technologies that could potentially be incorporated into the developing wellbeing program at the primary school, and into packages developed for students heading to boarding school for their secondary years. AEHRC attended the Returning Generation school camp and held digital technology sessions with the school children.

Aurukun State School has expressed interest in continued collaboration to improve wellbeing in primary school children, and the Secondary Student Co-ordinator has expressed in augmenting the digital packages currently made for students leaving for boarding school. In addition, Aurukun Elders have expressed interest in developing a range of digital recordings (video and VR) for capturing traditional knowledge sharing practices.

STUDENT OR POSTDOC HIGHLIGHT

Matthew Chesini, a talented tertiary student enrolled in a Bachelor of Biomedical Sciences at the University of Queensland, commenced working with AEHRC on an Indigenous cadetship in 2018. Matthew made significant contributions to a number of projects within the Biomedical Informatics and Health Services Group, gaining valuable experience in biomedical imaging, and sensor development and deployment. Matthew has been accepted into the University of Sydney School of Medicine in 2020.

HEALTH SYSTEM ANALYTICS

2018/19 SCIENCE AND IMPACT HIGHLIGHTS

- Publication in Nature Scientific Reports of the risk stratification tool used to identify patients who are at risk of hospitalisation for the Health Care Homes trial.
- In-hospital risk tool trialled at Logan Hospital to identify inpatients who are at risk of 30 day readmission.
- Delivery of the HealthLinks Chronic Care Evaluation Report Year-2 for the Department of Health, Victoria.
- New 30-day mortality measure developed for Acute Myocardial Infarction (AMI) for Victorian Agency for Health Information (VAHI).
- Environmental scan on measures and methodologies for Board Safety and Quality Reporting for Victorian Agency for Health Information (VAHI).
- New data analytics collaboration with WA Health and Fiona Stanley Hospital (FSH) commenced with a project to model emergency theatre demand and patient wait times to surgery at FSH.

Health System Analytics Group Leader: Dr Rajiv Jayasena

The Health System Analytics team 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 understanding how evidence-based practices get implemented as routine healthcare.

Health Implementation Science Team Leader: Mr Norm Good

The Health Implementation Science team undertakes research in health system evaluations, developing evidence and benefits realisations for new care/policy initiatives. The team also undertakes scientific investigations on how evidence-based practices are transitioned to routine healthcare.

Health Intelligence 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, the team has delivered significant impact in the space of patient flow analytics, and is well recognised as leaders in this research space.

HEALTH IMPLEMENTATION SCIENCE

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 of models of care and patient outcomes.

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

HEALTHLINKS CHRONIC CARE

HealthLinks Chronic Care (HLCC) is an initiative undertaken by the Victorian Department of Health and Human Services (DHHS) to provide a flexible funding model for participating hospitals to convert projected inpatient costs towards new or improved patient centred models of care, with the aim of reducing unplanned hospital admissions.

The hospitals identify patients who are at high risk of multiple unplanned hospital admissions through an algorithm and use converted funds to deliver care beyond traditional hospital based care models including services provided by external organisations.

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

COLLABORATORS:

- Victorian Department of Health and Human Services.

HIGHLIGHTS FOR 2018/19:

- Conducted more than 30 focus group surveys and individual interviews with health service providers from five participating health services to gain an in-depth understanding of the barriers and enabler of the HLCC funding model and how it is implemented in individual health services.
- Delivered a second annual report to the DHHS providing results comparing patient outcomes from participating health service site to control sites, and intervention to control ‘patients’.
- Secured a panel presentation for Pippa Niven and Norm Good at the Society for Implementation Research Conference 2019 in Seattle and a storyboard presentation at the Global Implementation Conference in Glasgow in October 2019.

AIMS FOR 2019/20:

- Finalise HLCC evaluation by May 2020 and present findings to HLCC Clinical Collaborative and DHHS.

POSTDOCTORAL FELLOW PROFILE

Dr Kay Mann
Project: “Real-time” deteriorating patient prediction.

This project aims to develop a range of predictive statistical models for use in the clinical setting to optimally manage patients. The transition of Queensland hospitals to fully digital integrated electronic medical records provides new opportunity for early detection and prevention of patient deterioration. The research question is to determine if digital data can be used to accurately predict the likelihood of a patient deteriorating in real time. The objective is to reduce the incidence of unexpected adverse, potentially preventable hospital events such as unplanned transfer to ICU, cardiac arrest and death.

PHD STUDENT PROFILE

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

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

HEALTH INTELLIGENCE

The Health Intelligence team develops and delivers scientifically robust analytics to improve safety, quality and efficiency of our healthcare system. These analytics improve performance and sustainability of the Australian health system by transforming clinical and operational data into knowledge via analytics; optimisation of patient, clinician and resource flows; real-time monitoring for decision support; and prediction and risk stratification tools.

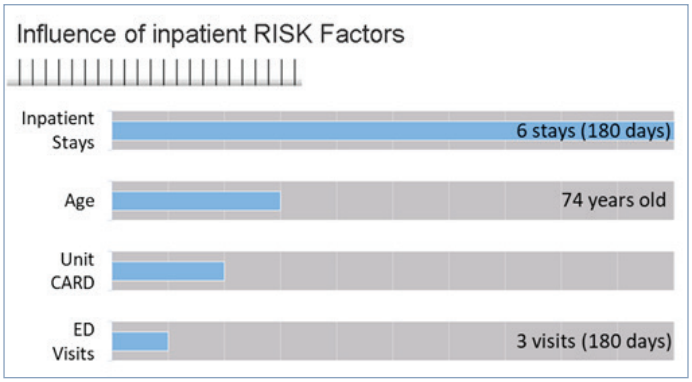
The work demonstrates an intimate knowledge of the Australian health system and associated datasets as well as knowledge of the regulatory frameworks of working with sensitive health data and potential quality issues associated with health data.

RISK STRATIFICATION FOR HOSPITAL AVOIDANCE IN ACUTE CARE

Partnering with the Queensland Health's Healthcare Improvement Unit and Logan Hospital, our team successfully delivered a real-time web-based risk stratification algorithm that can be used to identify chronic disease patients with a high risk of re-hospitalisation while they are still in hospital. Model development and validation involved employing routinely collected administrative and clinical datasets available in real time, and a web-based clinical decision support tool was built to provide risk groups and individual patient risk profiles to care teams.

A 24-month evaluation care planning process is underway at Logan Hospital to assess the impact of the risk tool on chronic disease re-admissions. This project was recently extended to develop and validate a statewide algorithm.

Figure 1: Patient-specific factors contributing to risk of readmission are provided for each inpatient via a dashboard.

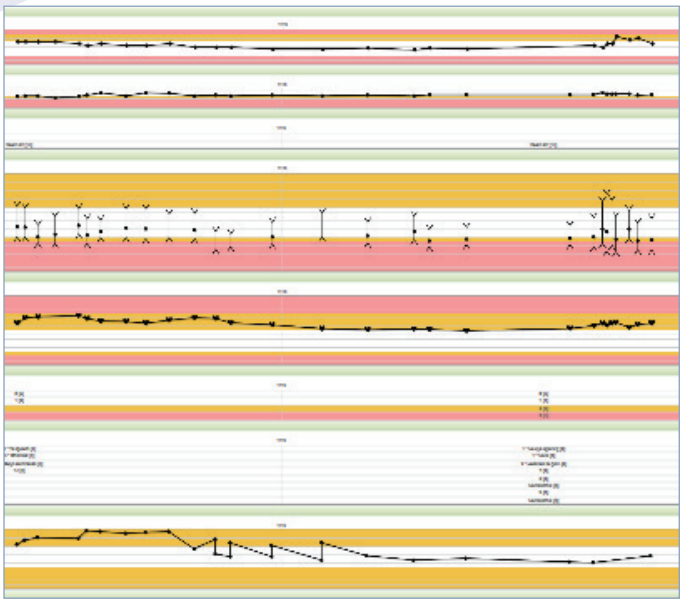


PREDICTING UNEXPECTED PATIENT DETERIORATION IN A DIGITAL HOSPITAL

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

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

Figure 2: In-hospital patient monitoring dashboard (Source: Clinical Informatics, Metro South Health).



IMPROVING SURGERY SCHEDULING IN PUBLIC HOSPITALS

The team continues to work with Queensland Health's Healthcare Improvement Unit to use statistical modelling of surgical and inpatient data to maximise the utilisation of operating theatres in hospitals.

This year the team has explored whether the day of the week that elective surgery is undertaken affects postoperative length of stay, whether sessions comprising the same medical specialty are more highly utilised than sessions with a mix of specialties, and whether more frail patients lead to longer procedure times and turnover times between operations. These insights into scheduling can be used by administrators in efforts to address current challenges in surgery scheduling practice.

PREDICTIVE APPOINTMENT NOTIFICATION TOOL

We have recently started a new project with Austin Health in Victoria to better predict appointment loads to specialist clinics to provide realistic scheduling, increased productivity of staff, and timely care delivery for patients. The aim is to develop innovative strategic solutions to help clinic managers manage the ever-growing outpatient specialist clinic waiting lists.

The team is using a modelling approach to predict the next available appointment whilst interpreting constantly changing waitlist volume and priorities, and to optimise clinic

templates across different types of appointments. This is expected to help specialist clinics achieve quality and safety objectives while increasing patient satisfaction.

DEFINING A NEW 30-DAY AMI MORTALITY MEASURE

The team was commissioned by Victorian Agency for Health Information (VAHI) to develop a 30-day mortality measure for acute myocardial infarction (AMI) which includes both in- and out-of-hospital mortality. Current hospital mortality measures only include deaths that happen in hospital. A measure of mortality that includes out-of-hospital death could capture potential variations in discharge practices and post-discharge care.

This project delivered both the rationale for the recommended statistical approach and recommended covariates to control for patient characteristics that may be associated with variation in 30-day in- and out-of-hospital AMI mortality.

Our recommendations to VAHI were:

- Use a logistic generalised linear mixed model with random intercept (i.e., random-intercept logistic regression) for risk adjustment for its 30-day AMI mortality measure as it appropriately addresses the lack of independence arising from multiple patients admitted to the same hospital.
- Use the following covariates for its new 30-day AMI mortality measure: age, age x age, STEMI indicator, same day indicator, marital status, BHI/ACSQHC comorbidities based on the index case only (specifically hypotension, shock, renal failure, heart failure, dysrhythmia, malignancy, hypertension and cerebrovascular disease), cardiac arrest indicator and diabetes indicator.

Following these recommendations, we also conducted investigations on the most appropriate measurement period, threshold and reporting frequency, as well as presenting visualisation options for the new 30-day in- and out-of-hospital AMI measure.

SYNDROMIC SURVEILLANCE

Syndromic surveillance is emerging as a cutting-edge health system management tool in Australia and overseas. The team has been assisting Queensland Health's efforts towards the detection of disease outbreaks in real time, from ED presentations and other data sources via the Queensland Health Syndromic Surveillance Working Group.

The initial focus of this group is influenza and "influenza like illness" (ILI). As a member of the working group, our initial pilot activities have been focused on identifying Emergency Department (ED) diagnosis codes that should be used to identify ILI, correlating ED presentations with laboratory-confirmed notifications and weather variables, and developing a model to detect a disease outbreak from hospital ED data.

Using extracts of data supplied by Queensland Health, it was possible to identify and characterise presentations made to the major public hospital EDs associated with influenza-like illnesses. Correlation of these diagnosis codes chosen to represent ILI activity with laboratory-confirmed influenza notifications was found to be very high, supporting their use in syndromic surveillance models based on ED data. Initial exploratory analysis assessed outbreaks using Exponentially Weighted Moving Averages, a process control method used in detecting anomalies in industrial production processes. This method relies on setting a threshold (control limit) relating to ILI ED presentations. Two approaches were assessed: a traditional approach of monitoring daily counts and an alternate method of monitoring the time between presentations, with the latter being more efficient at flagging an outbreak.

This analysis provides valuable insight to improve syndromic surveillance capability and assist Hospital and Health Services to plan and respond to variations in hospital emergency demand. The research also assists Queensland Health's efforts towards the detection of disease outbreaks in real time from ED presentations and other data sources.

LOGAN HOSPITAL PATIENT FLOW ANALYTICS

The primary objective of this research project is to identify strategies to improve bed access performance at Logan Hospital, a major metropolitan hospital in South East Queensland. The work involves evaluating the statistical relationship between time periods of care delivery and bed access performance indicators, including modelling:

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

A better understanding of flow bottlenecks will improve capacity management and care outcomes, and assist Logan Hospital in meeting performance targets. There may also be implications for patient flow management across other hospitals.

FIONA STANLEY HOSPITAL OPERATING THEATRE ANALYSIS

The Health Intelligence team is also undertaking projects with the Department of Health Western Australia. See the WA Data Analytics Projects page for details.

BOARD SAFETY AND QUALITY REPORTING METRICS

This project will assist the Victorian Agency for Health Information (VAHI) to define the structure, metrics and visualisation of the Board Safety and Quality Reports for all Victorian Health Services. Sixty-four hospital boards will be relying on these reports to gauge the quality and safety of their respective hospital services. This is a very high impact project and great exposure for the team where we will be working alongside a Victorian state government agency to define these important metrics and how they should be visualised in the board reports. This project will build upon existing work undertaken by VAHI in identifying a series of strategic measures that may be likely candidates for reporting under framework themes of the new Board Safety and Quality Report (BQSR) being developed.

HEALTH INTELLIGENCE (CONTINUED)

An environment scan will review available literature in the national and international context to identify big dot metrics suitable for inclusion. Existing methodologies for these will be detailed, and the implication for development of new metrics will be explored. A candidate set of metrics will be presented to the Expert Advisory Group (EAG) for consideration and review and the environmental scan will be finalised following inclusion of their feedback. A set of up to three novel metrics that can be employed without the need for significant development will be chosen from the final set of metrics in consultation with the EAG. Draft technical specifications will be developed for each of these metrics and provided to VAHI for implementation.

COLLABORATORS:

- Queensland Ambulance Service
- Healthcare Improvement Unit, Queensland Health
- Metro South Hospital and Health Service, Queensland Health
- Metro North Hospital and Health Service, Queensland Health
- Sunshine Coast Hospital and Health Service, Queensland Health
- Victorian Agency for Health Information
- Victorian Department of Premier and Cabinet
- Austin Health
- Victorian Department of Health and Human Services (DHHS)
- Precedence Health Care/Sonic Health Services
- Australian Government Department of Health
- WA Health.

HIGHLIGHTS FOR 2018/19:

- Publication of Health Care Homes paper in Nature Scientific Reports: "A risk stratification tool for hospitalisation in Australia using primary care data". The algorithm has also been made freely available through the Australian Government Department of Health website.
- Recommended the statistical approach and covariates for a new 30-day in- and out-of-hospital AMI mortality measure for VAHI.
- Implementation plan delivered for Austin Health Predictive Appointment Notification Tool.
- Logan Hospital risk stratification trial extended to a 24-month term. This project has also been extended to develop and validate a statewide algorithm.
- An interim report for the "Predicting unexpected patient deterioration" project was submitted to Queensland Health.
- An interim report for the "Syndromic Surveillance" project was submitted to Queensland Health.
- An interim report for the "Logan Hospital Patient Flow Analytics" project was submitted by the Metro South Hospital and Health Service.

AIMS FOR 2019/20:

- Deliver environmental scan for Board Safety and Quality Reporting to VAHI.
- Final report on measurement period, threshold and reporting frequency and visualisation options on 30-day in- and out-of-hospital AMI measure to VAHI.
- Develop proof-of-concept Predictive Appointment Notification Tool for Austin Health Specialist clinics.
- Theatre analysis report of surgery data at Fiona Stanley Hospital to gain insight into theatre efficiency and better target efforts to address current challenges in surgery scheduling practice.
- Final report for the Logan Hospital Patient Flow project to provide valuable insight critical to the development of initiatives aimed at improving the flow of patients through Logan Hospital and providing evidence around strategies that improve compliance against national performance targets.

PHD STUDENT PROFILE

Ms Kristin Edwards, Postgraduate Student

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

Venkata Tadi, Postgraduate Student

Venkata is a PhD student jointly supervised by the University of New South Wales, CSIRO, and the Australian Government Department of Health. His PhD research aims to investigate the physical health and social outcomes of Australians with serious mental illnesses, and to identify opportunities for policy intervention to prevent negative outcomes. This will be done by developing approaches to using linked national administrative and survey datasets to understand, predict and identify ways to better target services and improve service delivery for people living with co-morbid mental and physical health issues.

TRANSFORMATIONAL BIOINFORMATICS

2018/19 SCIENCE AND IMPACT HIGHLIGHTS:

- The group has published eight journal papers (six first/ senior author) and more than 25 conference papers (11 keynotes at major national and international conferences with up to 1000 attendees, 14 oral presentations, all presenter or senior author).
- Our work was featured in international media articles and blog posts (ZDNet, Medium) on publications potentially reaching millions of readers, and won CSIRO Health and Biosecurity's "Domain+Digital", "Social Media" and "Inclusion & Diversity" awards.
- The group has secured $1M in competitive funding and has engaged 14 companies in customer discovery conversations (e.g., Illumina, Sonic Health, Samsung, Sanford Health).

AIMS FOR 2019/20:

- Establish VariantSpark internationally as the technology of choice for large cohort analysis to capture part of the USD$18.9 billion (2020) genomics market (Markets and Markets1).
- Develop technology for gene therapy in collaboration with CMRI Westmead and Guangzhou Medical University to capture part of USD$7.5 billion (2024) genome editing market (Global Market Insights, Inc2.).
- Publish high impact journal publications and communicate the excitement and relevance of them to the general public through blog posts and media articles.

Transformational Bioinformatics Group Leader: Dr Denis Bauer

Our Transformational Bioinformatics research group develops clinically usable tools for the incorporation of large, complex and diverse life science datasets (such as high throughput sequencing, gene expression, proteomics) to facilitate better patient treatment and improved clinical outcomes.

Genome Insights Team Leader: Dr Natalie Twine

The Genome Insights team generates insights into genome-trait relations by analysing population-scale 'omics (genomics, transcriptomics, methylomics) and integrating with observational data.

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.

GENOME INSIGHTS

Genomic information is increasingly being used for medical research, giving rise to the need for efficient analysis methodologies able to cope with thousands of individuals and millions of genomic variants. The Genome Insights team has developed a suite of tools utilising machine learning, BigData Spark technology and serverless cloud computing to enable real-time genomic data analysis.

NHMRC DEMENTIA TEAM GRANT: MOTOR NEURONE DISEASE AND DEMENTIA

CSIRO is a partner in the Dementia Team Grant led by Prof Ian Blair and Dr Kelly Williams at Macquarie University, which aims to uncover the molecular mechanisms of Amyotrophic Lateral Sclerosis (ALS), also known as motor neurone disease (MND). CSIRO is responsible for the genomic data analysis of 800 Australian WGS ALS samples, as well as the data integration of other 'omics data collected through the lifespan of this five-year project. These samples form the Australian contribution to the international Project MinE consortium. CSIRO is also engaged in this wider initiative by analysing this 22,000 strong case-control cohort.

Outcomes

- Numerous publications in high impact journals: Cell Neuron (IF=14.024, cited 4), Scientific reports and a lead authorship currently on Bioarchive.
- The work has been presented by CSIRO as a keynote at the International Conference on Frontotemporal Dementias in Sydney.

CLOUD-BASED GENOME ANALYSIS TOOLS

This project develops novel approaches for analysing genomic data from population-scale cohorts resulting in the VariantSpark framework. As part of this framework, we have developed TRIBES, a user-friendly software pipeline that enables the discovery of distant relatives based on their genome. TRIBES identifies the shared genomic region between relatives, substantially narrowing the search space for the genomic origin of disease. Application cases include discovery of disease loci in large cohorts, removal of related confounding samples for Genome-wide association studies (GWAS) and family planning.

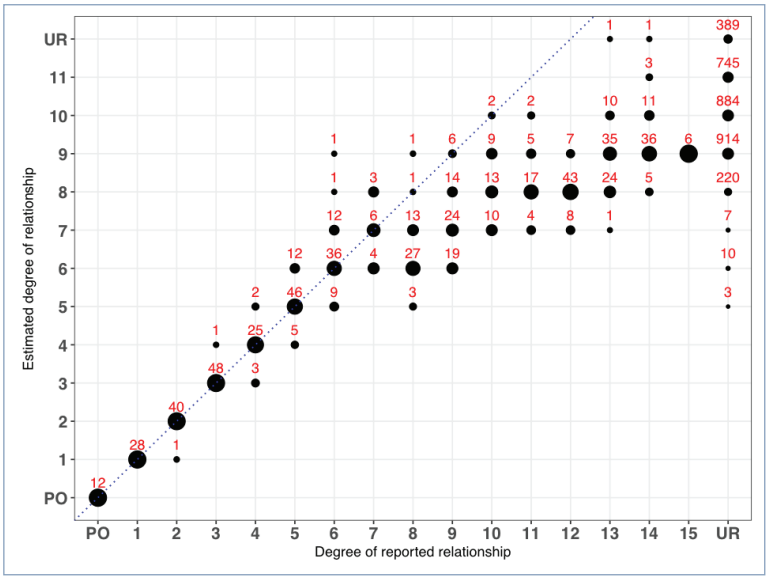
This project develops novel approaches for analysing genomic data from population-scale cohorts (i.e., common and rare variants). Our software platform VariantSpark has been demonstrated to save companies 80% of cost by requiring fewer samples for standard case-control studies (GWAS) to reach significance. It achieves this by using Apache Spark technology for building machine learning models capable of analysing the full genome simultaneously. This allows the tool to identify genomic locations that jointly contribute to disease as opposed to being limited to detecting only the strong individually contributing genes (GWAS).

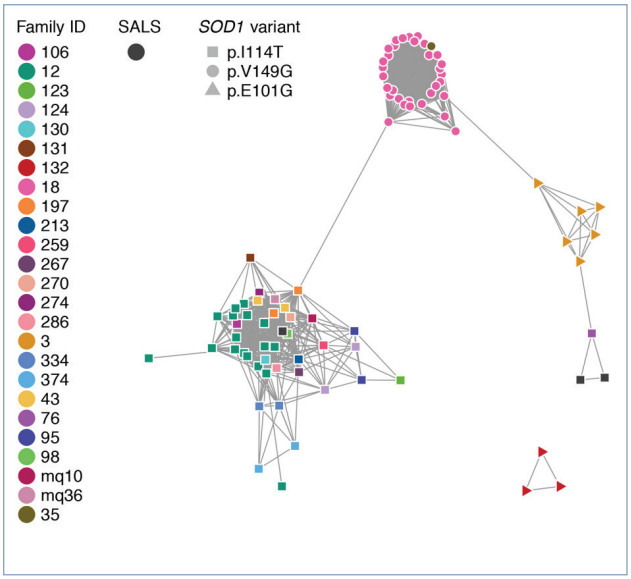
Outcomes

- TRIBES software is available on GitHub and preprint in Bioarchive.
- TRIBES and impact in the ALS field will be presented at largest Life Sciences conference ISMB, 2019.
- VariantSpark featured as one of ComputerWeekly's Top-10 IT stories of 2017 and in an interview on Futureproofing Companies.
- CSIRO presented VariantSpark as keynote presentation at international IT conferences (AgileIndia, AIDevDays) and AWS Summits in Canberra (2018) and Mumbai (2019).

Figure 1: (Left) The reported vs. estimated degree of relatedness in the ALS cohort using TRIBES.

(Right) Network of individuals sharing IBD segments over the known disease locus.





USING PROTEINS AS PROXY FOR HEALTH (DROP)

Together with an external client, Drop, we are performing a longitudinal analysis of protein biomarkers in the blood. In this project, customers will send blood samples at regular time points; these will be analysed to determine the concentration of specific markers which are indicative of the individual's health. Our team are building infrastructure and machine learning-based solutions to analyse and interpret the blood biomarker data.

Drop can then utilise results to provide information to customers on their health, disease predisposition and advice on how to regain "healthy" levels of blood markers.

Outcomes

- Securing a Kickstarter grant ($200K) to support Australian SMEs.
- Building essential infrastructure for processing and management of customer's biomarker data.
- Using custom built solutions, we have analysed the first set of customer data, to establish best practice methods.

SERVERLESS BEACON

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

We therefore partnered with Melbourne Genomics Health Alliance (MGHA) to develop a serverless approach to exchange human genomic information between organisations. The framework was architected to provide instantaneous analysis of non-local data on demand, with zero downtime and minimal running costs. We used Terraform to write the infrastructure, enabling rapid iteration and version control at the architecture level. In order to maintain governance over our infrastructure created in this way, we developed a custom Continuous Deployment service that built and securely maintained each project, providing visibility and security over the entire organisation's cloud infrastructure.

With the importance of genetic information in the clinic as well as the increasing size and quantity of data available, new processing methods are required. Our serverless implementation allows for the rapid querying of large datasets, streamlining the approach and reducing the time to progress from research to clinic.

Outcomes

- Our implementation led to an increased query speed of up to 2000% over conventional methods. Querying 100,000 genomes with 85 million variants was completed in 1 second, compared to the current average of 40 seconds.
- At a query rate of 100/hr, our implementation costs only 0.2% as much as the conventional method. To handle our cohort, it costs $7 per month, compared to $4000 per month if using traditional methods.
- We delivered the solution to MGHA and drew interest from AGHA and Genomics England.

Figure 2: Serverless Beacon: Helping take genomic analysis from the cloud to the clinic.

COLLABORATORS:

- Prof Ian Blair and Dr Kelly Williams, Macquarie University
- Prof Roger Chung, Macquarie University
- Project MinE ALS genomics consortium
- DropBio
- Melbourne Genomics Health Alliance.

GENOME INSIGHTS (CONTINUED)

HIGHLIGHTS FOR 2018/19:

- TRIBES available on Bioarchive and accepted as a talk at ISMB 2019.
- Collaborative work with Project MinE has been published in high impact journal Cell Neuron.
- Publications on ALS research with Macquarie University in Scientific Reports and Bioarchive.
- VariantSpark presented as keynote at international IT conferences (AgileIndia, AIDevDays).

AIMS FOR 2019/20:

- Extend our tool suite VariantSpark and TRIBES to AWS Marketplace, Azure Marketplace and Google Cloud Platform via Terra.
- Capitalise on work done with Project MinE and Macquarie University to publish further high impact ALS research.
- Develop a digital twin platform to model complex disease, with the aim of identifying novel therapeutic targets.

STUDENT PROFILES

Mischa Lundberg, QIMR

Topic: Integrating GWAS-style VariantSpark capability into PhenGen-Insight and demonstrate it on large medical genomics cohorts with FIHR-cap enabled phenotype data

Amyotrophic Lateral Sclerosis (ALS) and pain are highly heterogeneous phenotypes and can be caused by a multitude of medical conditions and, in case of pain, also by lifestyle factors such as a sedentary lifestyle. These possible influences make ALS and pain complex traits. To study the genetics underlying a trait, Genome Wide Association Study (GWAS) can become a powerful tool. GWAS aim to identify correlations between a genetic variant and a phenotype. To enhance insights into (complex) traits, researchers need computational and domain knowledge. To overcome such limitations, easy-to-use methods need to be available. This project focuses on the development and interconnection as well as improvement of given web-based platforms to conduct GWAS and post-GWAS, such as VariantSpark, Gen-Phen and the Complex Traits Genetics – Virtual Lab.

Louise Cui, Summer Vacation Student.

Topic: Developing a visual and interactive quality control pipeline for GWAS analysis

To conduct genome wide association studies (GWAS) with careful quality control, we developed a Jupyter notebook style automation of quality control (QC) and GWAS visualisations: ViGWAS. Leveraging Hail, ViGWAS is capable of parallel analysis of whole genome sequencing data, thereby enabling population-scale cohorts to be processed. Using cloud-based sample annotations, ViGWAS generates QC parameters, conducts association analysis and visualises output from analysis. We considered a comprehensive range of plots summarised in an output report for GWAS QC, and extended interactive features for plots to enable improved readability. ViGWAS greatly simplifies the process of conducting a quality GWAS for scientists with little programming knowledge.

DIGITAL GENOME ENGINEERING

New genome engineering technologies are currently revolutionising science, with impact fields such as precision health, diagnostics and biosecurity. However there are many challenges that need to be overcome before its full potential can be used. By applying digital genome engineering techniques, the Digital Genome Engineering team is working to help enable precision health applications.

COMPUTATIONAL GENOME EDITING SERVICES

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

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

Over the year we have established a cloud-based computational framework for designing a wide range of CRISPR-based experiments (available at https://gt-scan.csiro.au/).

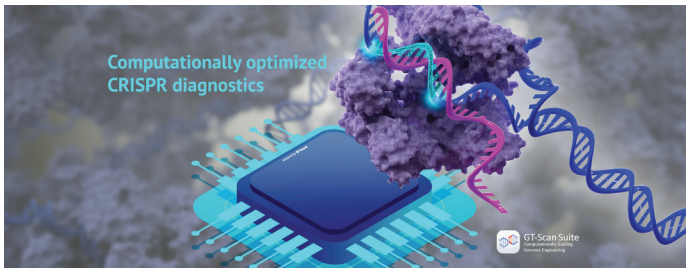
This platform is comprised of several published tools including TUSCAN (The CRISPR Journal) and VARSCOT (BMC Biotechnology). Our work has lead to a review on CRISPR-Cas9 predictive tools and been presented at many international conferences, including the main international CRISPR conference CRISPR2019 in Quebec City, Canada.

DETECTING FOREIGN DNA USING GENOMIC SIGNATURES

This project focuses on developing methods for detecting the presence of dangerous DNA within a genome, such as antimicrobial resistance genes among bacteria, or gene-drives within a population of viral integrations in a patient. Detection of these events is critical for both biosecurity and within the clinic. To address this, we developed an approach to detect whether foreign DNA has been inserted into a genome using the characteristic frequency of oligonucleotides in a genome (i.e., genomic signature). These oligonucleotides represent words within a genome, and every species has its own genomic vocabulary. By identifying regions of a genome that "sound" different to their surroundings, we can pinpoint bits of DNA that do not belong. This can be used to separate out inserted genes (e.g. gene-drives and bacterial plasmids), identify specific species among a large population, or monitor the spread of genetic traits. The technology can also be leveraged to create next-generation diagnostics, allowing users to accurately detect pathogens and distinguish between highly related strains.

The project is being lead by a new postdoc, Aidan Tay, who successfully won a CSIRO Acorn grant to design CRISPR-based diagnostics ($20K). Our work in this field has been published on multiple blog posts (Medium). We are also part of the OUTBREAK consortium, which successfully applied for MRFF funding ($1M) to research antimicrobial resistance.

2.1 Figure 1: CRISPR chip to revolutionise diagnostics.



IDENTIFYING VIRAL INTEGRATION SITES IN TUMOUR NGS DATA

Viral infections are implicated in around 10-15% of total human cancer cases. Associations between several viruses and neoplasia have been established for various types of cancer. Well-characterised examples include the association between human papillomavirus (HPV) and cervical cancers, as well as hepatitis B virus (HBV) and cancers of the liver (hepatocellular carcinoma, HCC). With the ever-increasing amount of genomic data available from biobanks and consortia such as the Cancer Genome Atlas (TCGA) and the International Cancer Genome Consortium (ICGC), we sought to explore whether viruses without previously established roles in cancer might be associated with particular cancer types.

We therefore aimed to investigate insertional mutagenesis in next-generation sequencing (NGS) data from cancer tissue and matched healthy control tissue. To analyse these data, in collaboration with the Gene Therapy Unit from the CMRI, Westmead, we developed a pipeline for the identification of viral integration sites. In this approach, we aligned reads first to the human and viral genomes, and then identified potential chimeric reads as evidence for integration. We then used this approach to search publicly available cancer sequence data for evidence of viral insertional mutagenesis in cancer tissue, but not healthy control tissue. Preliminary results confirm the role of known cancer-associated viruses in particular cancer types. We are now investigating the presence of viruses with no previous links to cancer in this dataset. Our findings may have implications for the prevention of cancers caused by novel cancer-associated viruses.

The collaboration with the CMRI, Westmead is being lead by our new postdoc Suzanne Scott. Suzanne successfully won a CSIRO Acorn grant to model viral capsid activity ($20K). We were also successful in our Research+ proposal, securing $250K for a postdoc fellowship to investigate influenza evolution.

DIGITAL GENOME ENGINEERING (CONTINUED)

COLLABORATORS:

- Prof. Goubing Chen, Jinan University
- National Measurement Institute
- Gene Therapy Unit, CMRI, Westmead
- Translational Vecterology Group, CMRI, Westmead.

HIGHLIGHTS FOR 2018/19:

- Publications for TUSCAN (The CRISPR Journal) VARSCOT (BMC Biotechnology) and Review of CRISPR-Cas9 predictive tools (Frontiers in Pharmacology).
- MRFF funding ($1M) and Research+ Postdoc ($250K).
- Presentation at one of the main international CRISPR conferences CRISPR19 in Quebec City, Canada.

AIMS FOR 2019/20:

- Develop a more refined predictive model for CRISPR-Cas9 that incorporates chromatin and transcription information.
- Develop a platform for the design and evaluation of CRISPR based diagnostics.
- Investigate the prevalence of viral integrations in cancer.
- Develop and refine a pipeline for detecting integrated DNA events in uncharacterised genomes.

STUDENT PROFILES

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

Genome editing is a new molecular discipline with transformative impact on human health, environmental and agricultural applications. Of particular promise is the ability to insert synthetic DNA into the genome at precise locations as enabled through CRISPR-Cas9 and homology-directed-repair. Being able to do this with precision and efficiency requires extensive computational optimisation processes. This project builds sophisticated machine learning models that enable researchers to identify the optimal genomic location for an intervention. Working together with Australia's premier research organisation and CRISPR facility, the computational tools will be validated on novel datasets and enable new application areas.

Jake Bradford, PhD candidate, Biomedical Data Science Lab at QUT.

Supervisor: Dr. Dimitri Perrin.

The key to utilising CRISPR-Cas9 for genomic research is better guide design, using computational methods. Many methods exist, including those from QUT and CSIRO, however refinements are needed to improve the performance and the quality of guide efficacy and specificity. This collaboration, between the Biomedical Data Science Lab at QUT and the Transformational Bioinformatics Lab at CSIRO, aims to incorporate the existing methods into a new pipeline for designing CRISPR experiments. The final cloud-based pipeline will be a streamlined method for designing optimal CRISPR experiments and will be an important resource for the field.

AUSTRALIAN TELE-HEALTH RESEARCH AND DEVELOPMENT GROUP

Director: Yogi Kanagasingam

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

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

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

The group has two key research areas:

◆ Remote delivery of clinical services

This stream focuses on the development and evaluation of remote delivery of clinical services to metro, rural and isolated populations. Using the Remote-I system or Android-based technology, patient images will be forwarded through existing internet services to specialist clinicians at major centres for evaluation. Applications in this stream include ophthalmology eye screening for aged care facilities and dentistry (a rural pilot study using an Android-based imaging system), burns (using advanced imaging techniques to grade wounds) and emergency medicine (development of an emergency telehealth service in collaboration with WACHS), amongst others.

◆ Disease diagnosis and screening technologies

This stream pursues research around Alzheimer's disease, hypertension, H.Pylori and stroke. The Alzheimer's disease study is designed to evaluate the use of curcumin (derived from turmeric) as a diagnostic marker which can be detected using high-resolution retinal imaging. In the stroke study, data from patients after they experience a first stroke are interrogated with the aim of identifying markers that are predictive of a second stroke, thereby providing a window for preventive interventions.

HIGHLIGHTS:

- First to deploy artificial intelligence-based grading system for diabetic retinopathy and other eye diseases into a real-world clinical setup, with results published in JAMA Open Network.
- Remote-I telemedicine system for screening of patients with diabetes was implemented and used for patient care at Royal Perth Hospital and REACH Clinic.
- Developed and evaluated an automated retinal imaging platform called VASP to measure ocular biomarkers.
- Developed and validated a mobile app called MICE, Medical Image Communication and Exchange, at the Fiona Stanley Hospital Burns Unit.
- Developed and validated an eConsent app, ECo app, at Fiona Stanley Hospital.
- Received funding from the Foundation for Children, NSW for a tele-dentistry project. We have developed a mobile phone-based imaging system for dentistry, which is being evaluated in NSW and WA.
- Attracted major funding from NeuroVision Imaging to conduct further clinical trials around AIzheimer's disease and eye imaging.
- In collaboration with Townsville Hospital, we have developed and evaluated a video streaming system for families to connect to Neonatal Unit to see their premature born baby remotely.
- Developing an AI-based grading system for eye diseases from optical coherence tomography (OCT) images, in collaboration with Doheny Eye Institute, University of California, Los Angeles, USA.

REMOTE DELIVERY OF CLINICAL SERVICES

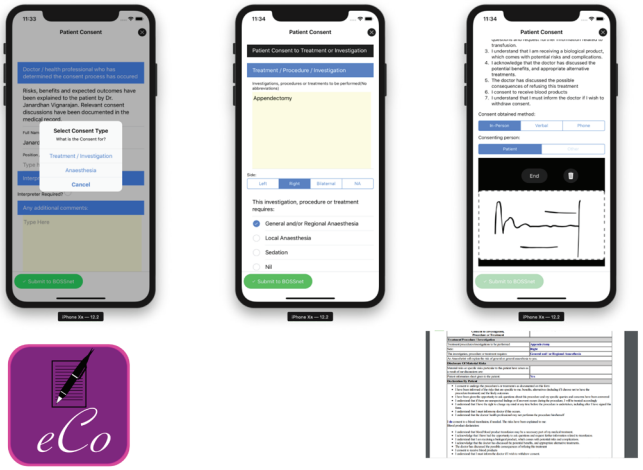
ECO: ELECTRONIC CONSENT FORM APP

Missing patient consent forms and the lack of consent form tracking has become a major issue in hospitals, causing many delays before medical procedures. Multiple health professionals (nurses, surgeons, interpreters and anaesthetists) are involved at multiple time points and need to work on a single consent form.

In collaboration with Fiona Stanley Hospital, we have developed a mobile app and a web-based system (based on our Medical Image Communication & Exchange platform, MICE) to provide a streamlined consent capture process.

We worked closely with Western Australia (WA) Department of Health IT staff to develop an integrated e-consent solution, known as eCo, which can be used by any approved WA Health worker. The solution is now being piloted at Fiona Stanley Hospital and is anticipated to be rolled out to other sites.

Figure 1: eCo app screenshots.



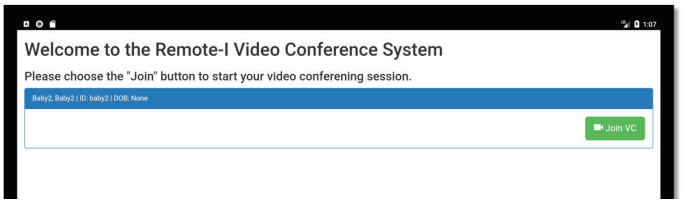
TELEMONITORING APP FOR PARENTS TO MONITOR THEIR PREMATURELY BORN BABIES

Babies born prematurely often have complex care needs, and may need to remain in a hospital's neonatal intensive care unit (NICU) for a month or more until they're healthy and developed enough to return home with their families.

This can be a stressful time for parents, who may have to return home while their new babies stay in hospital. Some parents live too far away to visit the hospital frequently, and the separation can affect their ability to bond with their newborn.

In collaboration with the Townsville Hospital Neonatal Unit in Northern Queensland and James Cook University, and with the donation of mobile phones from Optus, we developed and trialled a new private, secure and affordable app to give parents access to live video of their babies. First, a mobile phone is carefully and securely installed on the baby's cot. Once the app is installed on a parent's phone or tablet, they can securely log in over a 4G connection and watch a live-streamed video of their baby straight from their cot at NICU.

Figure 2: Telemonitoring app screenshot.



DEEP LEARNING SYSTEM FOR AUTOMATED ASSESSMENT OF AMD USING OCT

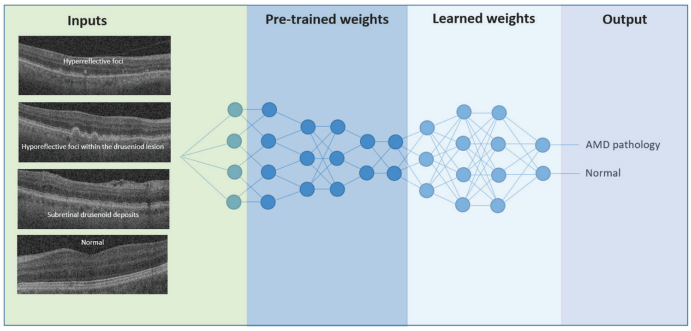
Age-related macular degeneration (AMD) affects millions of people and is a leading cause of blindness throughout the world. Ideally, affected individuals would be identified at an early stage before late sequelae such as outer retinal atrophy or exudative neovascular membranes develop, which can produce irreversible visual loss. Early identification would allow patients to be staged and appropriate monitoring intervals to be established, and accurate staging of earlier AMD stages could also facilitate the development of new preventative therapeutics.

However, accurate and precise staging of AMD, particularly using newer optical coherence tomography (OCT)-based biomarkers may be time-intensive and requires expert training which may not be feasible in many circumstances, particularly in screening settings.

In collaboration with Doheny Eye Institute, University of California Los Angeles, USA we have been developing deep learning methods for automated detection and classification of early AMD OCT biomarkers. Deep convolution neural networks (CNN) were explicitly trained for performing automated detection and classification of hyperreflective foci, hyporeflective foci within the drusen, and subretinal drusenoid deposits from OCT B-scans.

Numerous experiments were conducted to evaluate the performance of several state-of-the-art CNNs and different transfer learning protocols on an image dataset containing approximately 20,000 OCT B-scans from 153 patients. An overall accuracy of 87% for identifying the presence of early AMD biomarkers was achieved.

Figure 3: Deep learning for identifying the presence of early AMD biomarkers. Neuron connections shown here are for illustration only.



DEVELOPMENT OF MACHINE LEARNING TECHNIQUE TO ANALYSE LONGITUDINAL CHANGES RELATED TO DIABETES

This study relies on the longitudinal retinal image dataset named LANDMARK to assess the associations between micro-vascular changes and diabetes over time. The main focus is to develop new biomarkers which could predict early manifestation of diabetes and also identify patients at high risk of diabetic retinopathy. Using VASP (an in-house developed retinal vascular analysis platform) we computed vascular parameters on the baseline and follow-up images (already registered), then performed statistical analysis of vascular changes over time.

We are now drafting an article to summarise the findings. This project involved the development of a novel retinal image registration technique to facilitate image-wise comparisons of retinal images collected over time. In addition, we have developed a novel method to segment blood vessels in colour fundus photographs.

Figure 4: Matching bifurcation points relying on LHPB descriptor.

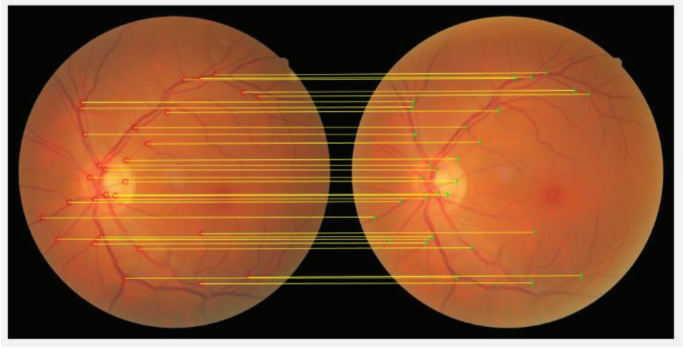
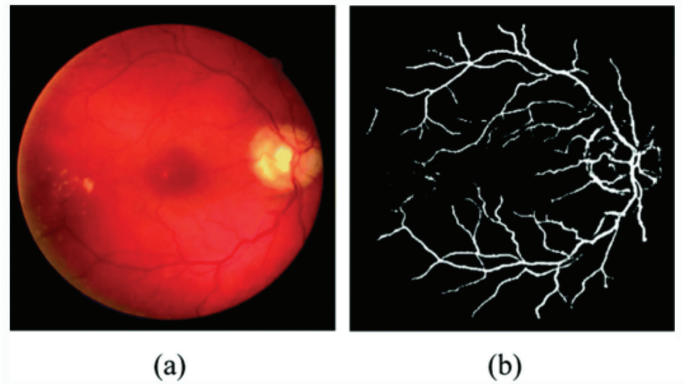


Figure 5: Sample outputs: (a) original image (b) vessel segmentation by the proposed method.



DEEP LEARNING METHOD FOR AUTOMATED ASSESSMENT OF PQCT SCANS

In collaboration with Edith Cowan University Western Australia, the University of Notre Dame Australia and Royal Perth Hospital, we have been developing a deep learning system to automatically determine the quality of peripheral quantitative computed tomography (pQCT) scans. This is particularly focused on eliminating scans with motion artefact, which at this stage predominantly relies on human-operated classification.

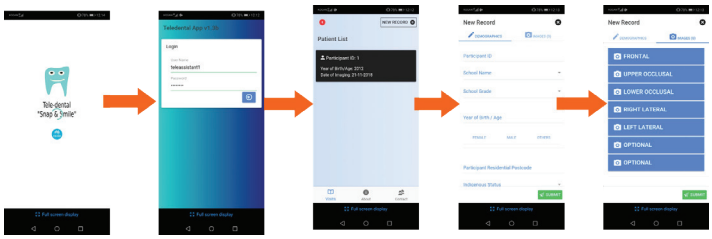
A total of 280 pQCT scans rated by a human expert were used to train and validate the model. This feasibility study evaluated the ability of three state-of-the-art deep learning models to detect motion artefact in pQCT scans and concluded that the deep learning approach appears to be a robust method to automatically and accurately detect motion artefact in reconstructed pQCT images.

TELEDENTISTRY FOR DENTAL CARE IN AUSTRALIAN SCHOOL CHILDREN

Historically, school dental therapists have been responsible for providing dental care for school children through the School Dental Services (SDS). The existing SDS has been unable to provide sustainable dental care to all school children due to a reduction in workforce participation and limited resources. Thus there is a need for an equitable and cost-saving model of dental care to enhance the opportunity to provide sustainable dental care for school children, particularly among those living in rural or remote regions.

We propose a paradigm shift in the current service through the introduction of user-friendly technology to provide a foundation for sustainable SDS. Using mobile technologies such as a smartphone camera, this project aims to acquire dental images from a child's mouth at their school, and forward images over the internet to an offsite dental practitioner to assess and prepare recommendations from a distance. Such an approach could enable dental practitioners to remotely assess the dental health of school children without needing to be physicallypresent. This would help prioritise high-risk children and provide them with quick treatment pathways, while avoiding unnecessary referrals and travel.

Figure 6: Flowchart of the image acquisition app used in dental photography.



REMOTE DELIVERY OF CLINICAL SERVICES (CONTINUED)

COLLABORATORS:

- Fiona Stanley Hospital
- WA Department of Health
- Fiona Wood Foundation
- The Townsville Hospital and Health Service, Queensland Health
- James Cook University
- Optus
- Doheny Eye Institute, University of California-Los Angeles, USA
- Edith Cowan University Western Australia
- The University of Notre Dame Australia
- Royal Perth Hospital
- The Financial Market Foundation for Children
- University of Western Australia
- University of Sydney
- Charles Sturt University
- LANDMARK Study group.

HIGHLIGHTS FOR 2018/19:

- eCo app deployed on both Android and Apple stores with a fully integrated solution with Hospital Electronic Medical Record System
- More than 35 families have taken part in the telemonitoring app trial for prematurely born babies since it began in early 2018, and initial feedback from parents has been very positive. We are now making the technology generally available by seeking additional collaboration with our partners across different states.
- Our initial work related to automated detection and classification of early AMD biomarkers using deep learning has been accepted for publication in Nature Scientific Reports.
- Our system to facilitate automated analysis of retinal changes related to diabetic retinopathy has been patented (Diagnostic imaging for diabetic retinopathy, Australian Patent Office, 2019900390).
- Initial baseline data collection for the teledentistry study has been completed (with more than 150 school children from six schools in WA) that included visual and photographic based caries assessment.
- The findings of the deep learning method for automated assessment of pQCT scans will be presented at the 29th Australian and New Zealand Bone and Mineral Society Annual Scientific Meeting in October 2019.

AIMS FOR 2019/20:

- Progressive eCo app rollout to various departments within South Metropolitan Health Service in WA and expansion to other health services within WA Health.
- Pursue further research in deep learning methods to develop a fully automated system in the context of pQCT to support better assessment of disease and analysis of progression.
- Assess the net economic benefits of using the teledental pathway of dental care versus the existing usual school dental care and the diagnostic performance of the photographic caries assessment relative to the visual dental examination approach.
- Pursue further research in developing deep learning techniques for more detailed assessment of early AMD biomarkers and their evolution in OCT.

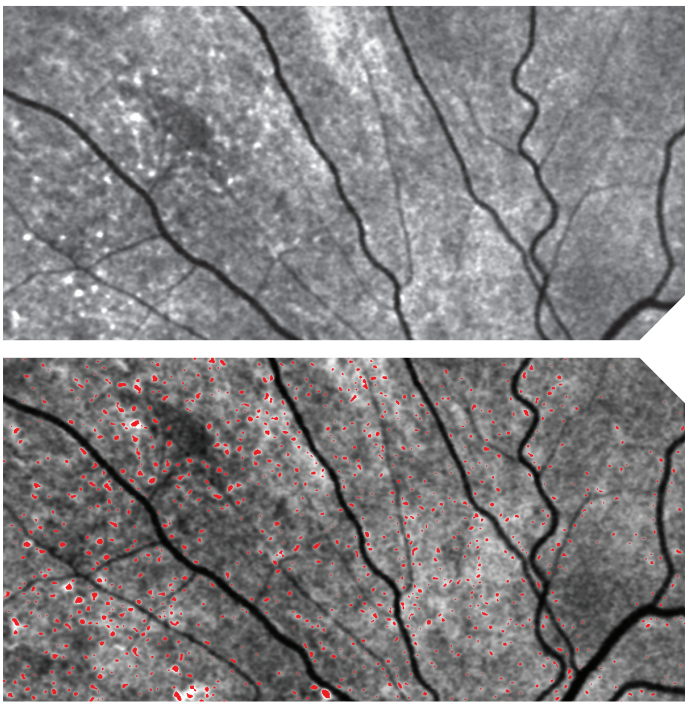
DISEASE DIAGNOSIS AND SCREENING TECHNOLOGIES

In this stream of work, we are exploring ways to develop biomarkers to screen and diagnose diseases early, so appropriate treatment and surgery can be provided in a timely manner. Our focus has been studying the changes related to vasculature and nerve tissue in the retina (at the back of the eye) and the cornea (front of the eye), in relation to various disease development such as stroke, hypertension, Alzheimer's disease, heart disease and ocular disorders. All data collection has been carried out in partnership with various Perth clinics.

OCULAR BIOMARKERS FOR ALZHEIMER'S DISEASE

We have been developing ocular biomarkers for early detection of Alzheimer's disease. The goal of this study is to see if a non-invasive and inexpensive eye test can detect the early, pre-clinical brain changes that occur up to 20 years before diagnosis. The trial involves two visits by volunteers to the Australian Alzheimer's Research Foundation, where they have their eyes tested using retinal image fluorescence photography. Between appointments, volunteers take a curcumin supplement, which is a natural ingredient used in cooking and also gives the spice turmeric its fluorescent yellow colour. We use curcumin to light up the amyloid-beta plaques in people's retinas. If what we see in the eye tests correlates with what is occurring in their brains, we will have the makings of a screening tool for Alzheimer's. It may enable us to identify early development of the disease, which could enhance our ability to intervene and stop or delay Alzheimer's progression.

Figure 1: A post-curcumin retinal fluorescence image from a patient positive to brain signs of Alzheimer's disease (PET SUVR = 2.13), and same image with detected fluorescent spots highlighted in red. Bright fluorescent spots are also visible in pre-curcumin images, but more are present post-curcumin and many have increased intensity.



Nidek device (N=200), Longitudinal study (N=100), Young controls (N=2) and New Eidon/Retia device (N=286). Preliminary results were presented at the Alzheimer's Association International Conference, the International Conference on Alzheimer's and Parkinson's diseases, and the Association for Research in Vision and Ophthalmology Annual Meeting, and a manuscript communicating these results is in preparation. Retinal imaging equipment, protocols and image analysis techniques have all been improved as a result of these studies, and the latest technology is being used for recruitment into the A4 AD-therapeutic trial and being tested in our recently completed clinical trial of 286 participants across Perth and Melbourne Australian Imagining and Biomarker Lifestyle (AIBL) sites.

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

Our cloud-based multi-modality intelligent retinal Vessel AnalysiS Platform (VASP) has been patented and utilised to search for further retinal markers of Alzheimer's. The latest trial data will be utilised for FDA validation of the test for early detection of Alzheimer's disease.

RETINAL IMAGING IN RESISTANT HYPERTENSION

In collaboration with Royal Perth Hospital Hypertension Clinic, this project aims to identify novel retinal imaging markers that may closely correlate with best practice blood pressure measurements and other signs of hypertensive organ damage in high risk patients. Such a retinal marker or set of markers may serve as an integral summation of the blood pressure burden a patient has been exposed to at any given time and provide a simple, non-invasive and inexpensive test for accurate prediction of cardiovascular risk. Longitudinal assessment and the corresponding changes in retinal markers may also serve as an indicator of adequate or inadequate anti-hypertensive treatment.

Data collection has been completed for 300 participants. Another trial on the effects of tropicamide pupil dilating eye drops on the retinal vasculature has been completed (N=42), and results were published in 2019.

DISEASE DIAGNOSIS AND SCREENING TECHNOLOGIES (CONTINUED)

PROGRESSION MONITORING IN JUVENILE MACULAR DISEASE

Funded by a Telethon grant, this collaboration with the Lions Eye Institute aims to develop automated progression analysis for fleck pathology in juvenile macular disease. Deep learning models have been developed and a manuscript is being prepared for TVST, an ARVO journal.

Figure 2: Retinal image showing flecks as observed in juvenile macular disease.

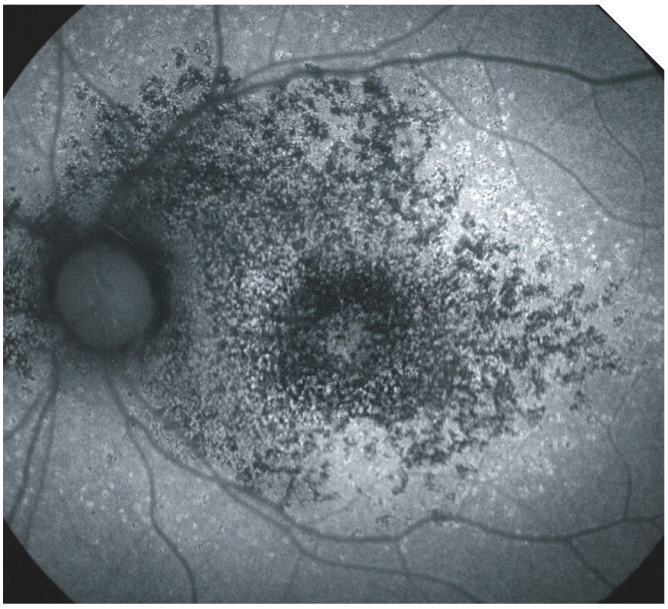
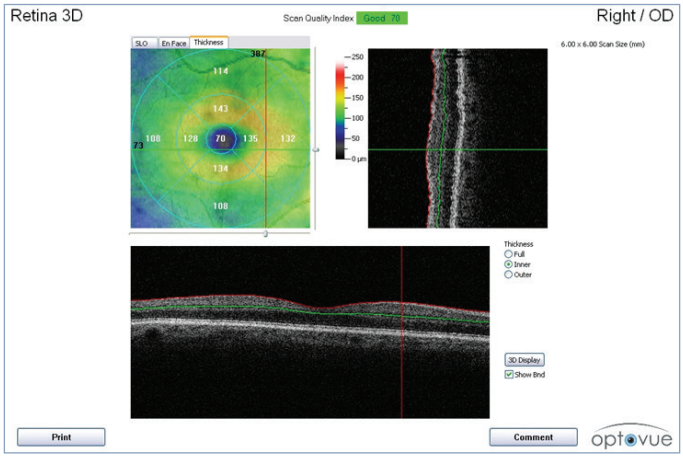


Figure 3: Retinal optical coherence tomography (OCT) identifying inflammation and subsequent atrophy in retinal layer thickness.



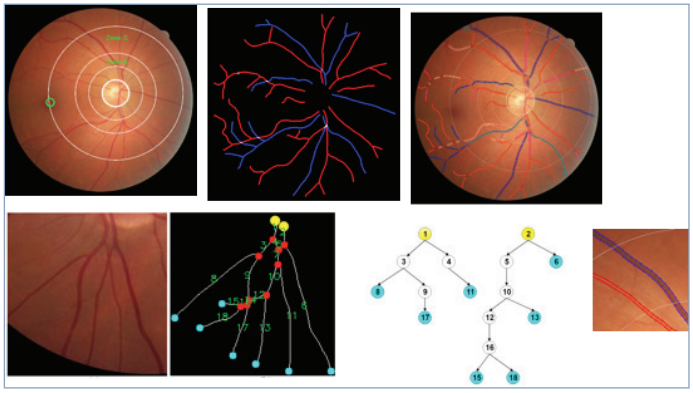
VASP: VESSEL ANALYSIS SOFTWARE PROGRAM

VASP is a cloud-based Vessel Analysis Software Program, developed in 2016/17 to address the need to provide disease risk analysis from the eye. More than 80 vascular parameters for biomarker research can be measured using VASP. The findings from research using VASP enable disease diagnosis and preventative management.

Rigid inter-user and intra-user repeatability studies have been performed to validate the reliability of VASP measured parameters, with an Intraclass correlation coefficient (ICC) score of >=91.9% for fractal dimension, >=90.7% for lacunarity, >= 95.9% for tortuosity and >=86.8% for vessel width parameters. VASP has also been utilised in a preliminary clinical study to confirm a relationship between blood pressure and width related parameters. The mean arterial blood pressure exhibited an inverse association with arteriolar diameter (Pvalue = 0.003) and arteriolar/venular ratio (AVR) (Pvalue = 0.001). The VASP validation study manuscript has been submitted to the Journal of Medical Systems.

VASP is being utilised to explore retinal biomarkers in disc and macular centered images (colour, infrared, fluorescence modalities) in our Alzheimer's, hypertension and other studies.

Figure 4: VASP image processing modules detect vessel tree structures, classify artery/vein, and measure vessel thickness at various regions.



OCT IMAGING TECHNOLOGIES

A collaboration with Queensland University of Technology (QUT). this project aims to develop a suite of OCT retinal imaging tools that enable analysis of OCT images of patients in different cohorts of study. A data transfer agreement is signed between the two parties, and we are receiving hundreds of OCT images from QUT to enable us to implement data rich methods that can identify layer boundaries accurately.

COLLABORATORS:

- Neurovision Imaging, Sacramento, California
- Hollywood Private Hospital (Ramsay Health Care)
- Royal Perth Hospital
- University of Western Australia
- Lions Eye Institute
- Australian Alzheimer's Research Foundation
- Sir Charles Gairdner Hospital
- Perron Institute for Neurological and Translational Science
- Queensland University of Technology (QUT)

HIGHLIGHTS FOR 2018/19:

- Neurovision clinical trial completed (n=286): external funding from Janssen, next-generation retinal fluorescence imaging in AD.
- Tropicamide study completed and published.
- Achieved target recruitment and data collection for 300 participants in the RPH Hypertension study.

AIMS FOR 2019/20:

- Pursue further Neurovision trial for FDA accreditation of eye test for AD with new imaging technology and protocols.
- Publish AD, hypertension and SAHMRI study results.
- Explore AI analysis techniques for hypertension data set.
- Develop RPH studies into additional clinical areas.
- Complete HPH trial on H.Pylori infection and retinal inflammatory markers.
- Transfer retinal biomarkers stroke study to patients at Sir Charles Gairdner Hospital due to stroke clinic closure at Royal Perth Hospital.
- Redefine the stroke study to explore people with secondary stroke.

WA DATA ANALYTICS PROJECTS

FIONA STANLEY HOSPITAL OPERATING THEATRE ANALYSIS

In 2018, staff from the Department of Anaesthesia & Pain Medicine at Fiona Stanley Hospital (FSH) approached our Health Intelligence team to help them model emergency theatre demand and patient wait times to surgery. This project is a quality improvement activity due for completion in June 2020, with the aim of improving patient access to surgery at FSH and developing and validating the accuracy of a predictive model (based on historical data) that allows better theatre management for emergency and elective case workload at the hospital.

This project's outcomes are anticipated to assist FSH staff to understand the relationship between emergency and elective surgery scheduling at the hospital, and what improvements can be made to increase the likelihood of FSH achieving their emergency surgery targets.

FSH's achievement of the emergency targets are monitored and performance managed via the Health Service Performance Report (HSPR) and monthly performance review meetings with relevant WA Health delegates. The work is also aligned with the WA Health 2019 Sustainable Health Review Report around investment in digital healthcare, health informatics and predictive analytics using modern technology, development of analytical capability, and supporting clinical and corporate users including consideration of partnerships.

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2. W. Billingsley, R. Torbay, P. Fletcher, R. Thomas, J. Steel, J. Suess, "Scaling a Studio-Based Distributed Software Engineering Course from a Large Local Cohort to a Small Global Cohort", *ACM Transactions on Computing Education*, vol. 19, pp. 13:1--13:27, Jan 2019.

3. S. Bollmann, K. O'Brien, A. Fazlollahi, M. Barth, "SHARQnet - Sophisticated Harmonic Artifact Reduction in Quantitative Susceptibility Mapping using a Deep Convolutional Neural Network", *Zeitschrift fur Medizinische Physik*, vol. 29, pp. 139-149, May 2019.

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5. N. Bradfield, K. Ellis, G. Savage, P. Maruff, S. Burnham, D. Darby, N. Lautenschlager, R. Martins, C. Masters, S. Rainey-Smith, J. Robertson, C. Rowe, M. Woodward, D. Ames, "Baseline Amnestic Severity Predicts Progression From Amnestic Mild Cognitive Impairment to Alzheimer Disease Dementia at 3 Years", *Alzheimer Disease & Associated Disorders*, vol. 32, pp. 190–196, Jul 2018.

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7. B. Brown, N. Castalanelli, S. Rainey-Smith, J. Doecke, M. Weinborn, H. Sohrabi, S. Laws, R. Martins, J. Peiffer, "Influence of BDNF Val66Met on the relationship between cardiorespiratory fitness and memory in cognitively normal older adults", *Behavioural Brain Research*, vol. 362, pp. 103-108, Apr 2019.

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AEHRC AND E-HEALTH PROGRAM STAFF, STUDENTS AND VISITORS

STAFF

Dr David Hansen, Chief Executive Officer

Ms Marianne Chalk, Program Support Officer / Office Manager

Mrs Janet Fox, Business Development Manager

Ms Sian Stringer, Communications Advisor

Ms Kate Birch, Principal Research Consultant

Mr Ray Mahoney, Senior Research Scientist

HEALTH INFORMATICS

Dr Michael Lawley, Group Leader and Principal Research Scientist

Mr Derek Ireland, Team Leader and Senior Software Engineer

Dr Anthony Nguyen, Team Leader, and Senior Research Scientist

Dr Alejandro Metke, Team Leader, and Senior Research Scientist

Ms Kate Ebrill, Product Manager, Clinical Terminology

Dr Hugo Leroux, Senior Research Scientist

Ms Donna Truran, Senior Engineer

Dr Andrew Patterson, Research Scientist

Dr Hoa Ngo, Postdoctoral Fellow

Ms Madonna Kemp, Senior Engineer

Mr Harrisen Scells, Postgraduate Student

Ms Kylynn Loi, Senior Research Scientist

Dr Bevan Koopman, Research Scientist

Ms Robyn Richards, Senior Research Scientist

Dr Thanh Vu, Postdoctoral Fellow

Mr Ming Zhang, Senior Engineer

Dr Jim Steel, Senior Software Engineer

Mrs Deanne Ukovich, Senior Engineer

Mr Simon Gibson, Senior Engineer

Ms Karen Harrap, Senior Engineer

Mr John O'Dwyer, Senior Engineer

Mr John Grimes, Principal Research Consultant

Mr David Conlan, Senior Software Engineer

Leibo Liu, Postgraduate Student

Anton van der Vegt, Postgraduate Student

Miles Seidel, Postgraduate Student

HEALTH SYSTEM ANALYTICS GROUP

Dr Rajiv Jayasena, Group Leader and Principle Research Consultant

Mr Norm Good, Team Leader and Principal Research Consultant

Dr Sankalp Khanna, Team Leader and Senior Research Scientist

Dr Kay Mann, Postdoctoral Fellow

Ms Philippa Niven, Senior Experimental Scientist

Dr Yang Xie, Postdoctoral Fellow

Dr Justin Boyle, Principal Research Scientist

Dr Hamed Hassanzadeh, Research Scientist

Dr Sandra Louise, Research Scientist

Dr David Rolls, Research Scientist

Ms Kristin Edwards, Postgraduate Student

James Kemp, Postgraduate Student

Marko Simunovic, Postgraduate Student

Venkata Tadi, Postgraduate Student

BIOMEDICAL INFORMATICS GROUP

Dr Jurgen Fripp, Group Leader and Principal Research Scientist

Dr Olivier Salvado, Group Leader and Principal Research Scientist

Dr Jason Dowling, Team Leader and Research Scientist

Ms Jessica Bugeja, Postgraduate Student

Dr James Doecke, Team Leader and Senior Research Scientist

Dr Sam Burnham, Team Leader and Statistician

Dr Vincent Dore, Senior Research Scientist

Dr Kaikai Shen, Research Scientist

Mr Alex Zahnleiter, PhD Student

Ms Ying Xia, Postdoctoral Fellow

Dr Pierrick Bourgeat, Senior Research Scientist

Dr Jeremy Beaumont, Postgraduate Student

Dr Biting Yu, Postgraduate Student

Mr Jason Wood, Research Assistant

Mr Ashley Gillman, Experimental Scientist

Mr Matthew Chesini, Research Assistant

Dr Susmita Saha, Postdoctoral Fellow
Mr Anthony Paproki, Postdoctoral Fellow
Ms Suzannah Cooper, Industrial Trainee
Mr Caleb Stewart, Postgraduate Student
Dr Kerstin Pannek, Research Scientist
Dr Ales Neubert, Research Scientist
Dr Dale Roach, Postgraduate Student
Ms Chia-Yin Wu, Research Assistant
Dr Alex Pagnozzi, Postdoctoral Fellow
Dr Lee Reid, Postdoctoral Fellow
Dr Ibrahima Diouf, Research Scientist
Dr Parnesh Raniga, Research Scientist
Dr Marcela Cespedes, Postdoctoral Fellow
Dr Amir Fazlollahi, Research Scientist
Dr Saba Momeni, Postgraduate Student
Dr Michael Vacher, Postdoctoral Fellow
Ms Julie Trinder, Research Assistant
Mr Rodrigo Santa Cruz, Postdoctoral Fellow
Dr Rosita Shishegar, Postdoctoral Fellow
Mr Malav Bateriwala, Postgraduate Student
Ms Miranda Li, Postdoctoral Fellow
Mr Jarryd Buckley, Postgraduate Student
Mr Stenzel Cackowski, Postgraduate Student
Dr Simon Puttick, Research Scientist
Mr Aninda Saha, Industrial Trainee
Ms Liza van Eijk, Postgraduate Student
Dr Simon McBride, Principal Research Consultant
Rob Finnegan, Postgraduate Student

TRANSFORMATIONAL BIOINFORMATICS GROUP

Dr Denis Bauer, Group Leader and Senior Research Scientist

Dr Natalie Twine, Team Leader
Dr Laurence Wilson, Team Leader
Dr Arash Bayat, Postdoctoral Fellow
Mr Brendan Hosking, Engineer
Mr Daniel Reti, Research Technician
Mr Aidan Tay, Postdoctoral Fellow
Ms Suzanne Scott, Postdoctoral Fellow
Mr Yatish Jain, IT Advisor
Mr Aidan O'Brien, Postgraduate Student
Mr Amnon Bleich, Postgraduate Student
Mr Mischa Lundberg, Postgraduate Student

HEALTH SERVICES

Dr Mohan Karunanithi, Group Leader and Principal Research Scientist

Dr Marlien Varnfield, Team Leader and Research Scientist
Ms Anna Kubiak, Research Technician
Dr Qing Zhang, Team Leader and Senior Research Scientist
Dr Amir Aminbeidokhti, Postdoctoral Fellow
Dr David Silvera-Tawil, Team Leader and Research Scientist
Dr Geremy Farr-Wharton, Postdoctoral Fellow
Dr Sazzad Hussain, Research Scientist
Dr Jane Li, Senior Experimental Scientist
Dr Dana Kai Bradford, Senior Research Scientist
Dr Janine Walker, Senior Research Scientist
Ms Ziggy O'Reilly, Postgraduate Student
Ms Yi Xiao, Honours Student
Dr Christian Redd, Postdoctoral Fellow
Dr David Ireland, Research Scientist
Dr Hang Ding, Research Scientist
Dr Vasu Rani, Postdoctoral Fellow
Dr Manuel Gonzalez-Garcia, Postdoctoral Fellow
Miss Vanessa Smallbon, Engineer
Dr Son Tran, Postdoctoral Fellow
Dr Jill Freyne, Team Leader and Principal Research Scientist
Prof Celler Branko, Adjunct Science Fellow
Ms Janine Walker, Senior research Scientist
Ms Sarah Bainbridge, Research Assistant
Dr Mahnoosh Kholghi, Postdoctoral Fellow

AEHRC AND E-HEALTH PROGRAM STAFF, STUDENTS AND VISITORS (CONTINUED)

Ms Julia Bomke, Project Officer

Ms Liesel Higgins, Project Manager

Ms Sal Martin, Project Officer

Ms Kaz Roebuck, Project Officer

Ms Parvaneh Shayegh Boroujeni, Postgraduate Student

Ms Yann Connan, Industrial Trainee

Mr Omrik Choudhury, Research Technician

Ms Nazli Bashi, Postgraduate Student

Ms Ying Xiao, Postdoctoral Fellow

Mr Hugo Delacour, Postgraduate Student

Dr Mohamed Estai, Postdoctoral Fellow

Ms Yashodhya Wijesinghe, Postgraduate Student

Saminda Balasuriya, Postgraduate Student

AUSTRALIAN TELE HEALTH RESEARCH AND DEVELOPMENT GROUP

Prof K Yogesan, Senior Principal Research Scientist, WA

Dr Shaun Frost, Senior Research Scientist

Dr Farhad Fatehi, Postdoctoral Fellow

Dr Di Xiao, Research Scientist

Mrs Maryam Mehdizadeh, Senior Research Technician

Dr Sajib Saha, OCE Postdoctoral Fellow

Mr Janardhan Vignarajan, Senior Engineer

Dr Cirous Dehghani, Postdoctoral Fellow

Dr Cheryl Chen, Experimental Scientist

Mr Victor Jouve, Industrial Trainee

Ms Mel Lawther, Research Technician

FUTURE SCIENCE PLATFORM

Prof Stephen Rose, Future Science Platform Leader

VACATION SCHOLARSHIP STUDENTS

Ms Cui Lujing, University of NSW

Mr Ilia Tikhomirov, Australian National University

Mr Dylan Panacheril, Monash University

Mr Tze Thong Khor, University of Queensland

Mr Jaspreet Singh, Griffith University

Mr Yikai Yang, Sydney University

Ms Grace Peng, University of NSW

Mr Kausthubram Rajesh, University of Queensland

Mr Scott Whittington, University of Queensland

Mr Aninda Saha, University of Queensland

Ms Yang Gao, University of Sydney

Mr Siyu Liu, University of Queensland

Ms Isobel Hunt, University of Melbourne

Mr Daniel Cheung, University of Queensland

Mr Jianwen (Simon) Yang, University of NSW

Ms Charlotte Middleton, Sydney University

VISITORS

Prof Mark Braunstein, Georgia Institute of Technology, Atlanta, USA July 2018 - December 2018, June 2019

Mr Roger Baker, Visiting Scientist June 2014 - current

Dr Shekhar Chandra, Visiting Scientist August 2011 - current

Erica Wallace, Visiting Scientist July 2011 - current

Dr Alison White, The University of Queensland January 2019 to December 2019

Christine Guo, Visiting Scientist June 2016 - current

Dr Lyndal Henden, Visiting Scientist October 2018 - current

SUPPORT STAFF

Finance - Kellie Tighe

HR - Laurie Mackenzie

Finance Support - Katie Forrestier

Contract Support - Sandy Fairnworth

HSE Support - Shane Casson

HSE Support - Megan Tilley

Business Development Support - Dr Peter Kambouris

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

(AN UNINCORPORATED JOINT VENTURE)

SPECIAL PURPOSE FINANCIAL REPORT

30 JUNE 2019

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

DIRECTORS DECLARATION

The directors have determined that the unincorporated joint venture is not a reporting entity and that this special purpose financial report should be prepared in accordance with the terms of the joint venture agreement and the accounting policies outlined in Note 1 to the financial statements.

The directors declare that the accompanying Statement of Comprehensive Income, Statement of Financial Position, Statement of Cash Flows, Statement of Changes in Joint Venture Funds and Notes to the Financial Statements present fairly the unincorporated joint venture's financial position as at 30 June 2019 and its performance for the year ended on that date in accordance with the terms of the joint venture agreement and the accounting policies described in Note 1 to the financial statements.

This declaration is made in accordance with a resolution of the Board.

Director PROF KEITH MENGERSEN

Brisbane
Date: 19 AUG 2019

Director ADRIAN TURNER

Brisbane
Date: 19 AUG 2019

Director BRUCE LINDSAY

Brisbane
Date: 19.8.19

Director ROB GRENFELL

Brisbane
Date: 28/AUG/2019

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INDEPENDENT AUDITOR'S REPORT

TO THE DIRECTORS OF THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

Report on the Audit of the Financial Report

Opinion

We have audited the accompanying special purpose financial report of The Australian E-Health Research Centre ("the unincorporated joint venture"), which comprises the statement of financial position as at 30 June 2019, and the statement of comprehensive income, statement of changes in joint venture funds and statement of cash flows for the year then ended, notes comprising a summary of significant accounting policies, other explanatory information and the directors' declaration.

In our opinion, the accompanying financial report presents fairly, in all material respects, the financial position of the unincorporated joint venture as at 30 June 2019 and its financial performance and its cash flows for the year then ended in accordance with the accounting policies described in Note 1 to the financial statements.

Basis for Opinion

We conducted our audit in accordance with Australian Auditing Standards. Our responsibilities under those standards are further described in the *Auditor's Responsibilities for the Audit of the Financial Report* section of our report. We are independent of the unincorporated joint venture in accordance with the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110: *Code of Ethics for Professional Accountants* (the Code) that are relevant to our audit of the financial report in Australia. We have also fulfilled our other ethical responsibilities in accordance with the Code.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Basis of Accounting

We draw attention to Note 1 to the financial statements which describes the basis of accounting. The financial report has been prepared to assist The Australian E-Health Research Centre to meet the requirements of the Joint Venture Agreement with Commonwealth Scientific and Industrial Research Organisation and the State Government of Queensland. As a result the financial report may not be suitable for another purpose. Our opinion is not modified in respect of this matter.

Responsibilities of the Directors' for the Financial Report

The directors of the unincorporated joint venture are responsible for the preparation and fair presentation of the financial report in accordance with the joint venture agreement and the accounting policies described in Note 1 to the financial report. The directors are also responsible for such internal control as they determine is necessary to enable the preparation and fair presentation of the financial report that is free from material misstatement, whether due to fraud or error.

In preparing the financial report, the directors are responsible for assessing the unincorporated joint venture's ability to continue as a going concern, disclosing, as applicable, matters relating to going concern and using the going concern basis of accounting unless the directors either intends to liquidate the unincorporated joint venture or to cease operations, or has no realistic alternative but to do so.

Auditor's Responsibilities for the Audit of the Financial Report

Our objectives are to obtain reasonable assurance about whether the financial report as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with the Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

As part of an audit in accordance with Australian Auditing Standards, we exercise professional judgement and maintain professional scepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the financial report, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.
- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the unincorporated joint venture's internal control.
- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by the unincorporated joint venture.

COVER OF EXCELLENCE

Chatswood Office:
Suite 302, 12 Help Street Chatswood NSW 2067 Australia
PO Box 5485 West Chatswood NSW 1515 Australia
T 61 2 9410 6999 | F 61 2 9410 6900

Katoomba Office:
94 Lurline Street Katoomba NSW 2780 Australia
PO Box 670 Katoomba NSW 2780 Australia
T 61 2 4782 2587 | F 61 2 4782 6458

mail@trumans.com.au | www.trumans.com.au | ABN 19 787 119 376
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- Conclude on the appropriateness of the unincorporated joint venture's use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the association's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditor's report to the related disclosures in the financial report or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditor's report. However, future events or conditions may cause the association to cease to continue as a going concern.
- Evaluate the overall presentation, structure and content of the financial report, including the disclosures, and whether the financial report represents the underlying transactions and events in a manner that achieves fair presentation.

We communicate with the directors regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit

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Peter Bray
Partner

Chatswood

Dated: 2 September 2019


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The Australian e-Health Research Centre
Level 5, UQ Health Sciences Building 901/16
Royal Brisbane and Women's Hospital
Herston QLD 4029 Australia
P +61 7 3253 3600
F +61 7 3253 3690
E enquiries@aehrc.com
aehrc.com

Acknowledgments
Editorial: Dr David Hansen, the Australian e-Health Research Centre
Marianne Chalk, the Australian e-Health Research Centre
Sian Stringer, CSIRO

CSIRO

Queensland Government

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

LEADING THE WAY IN HEALTH IT RESEARCH