

THE AUSTRALIAN  
**EoHEALTH**  
RESEARCH CENTRE

LEADING THE WAY IN HEALTH IT RESEARCH



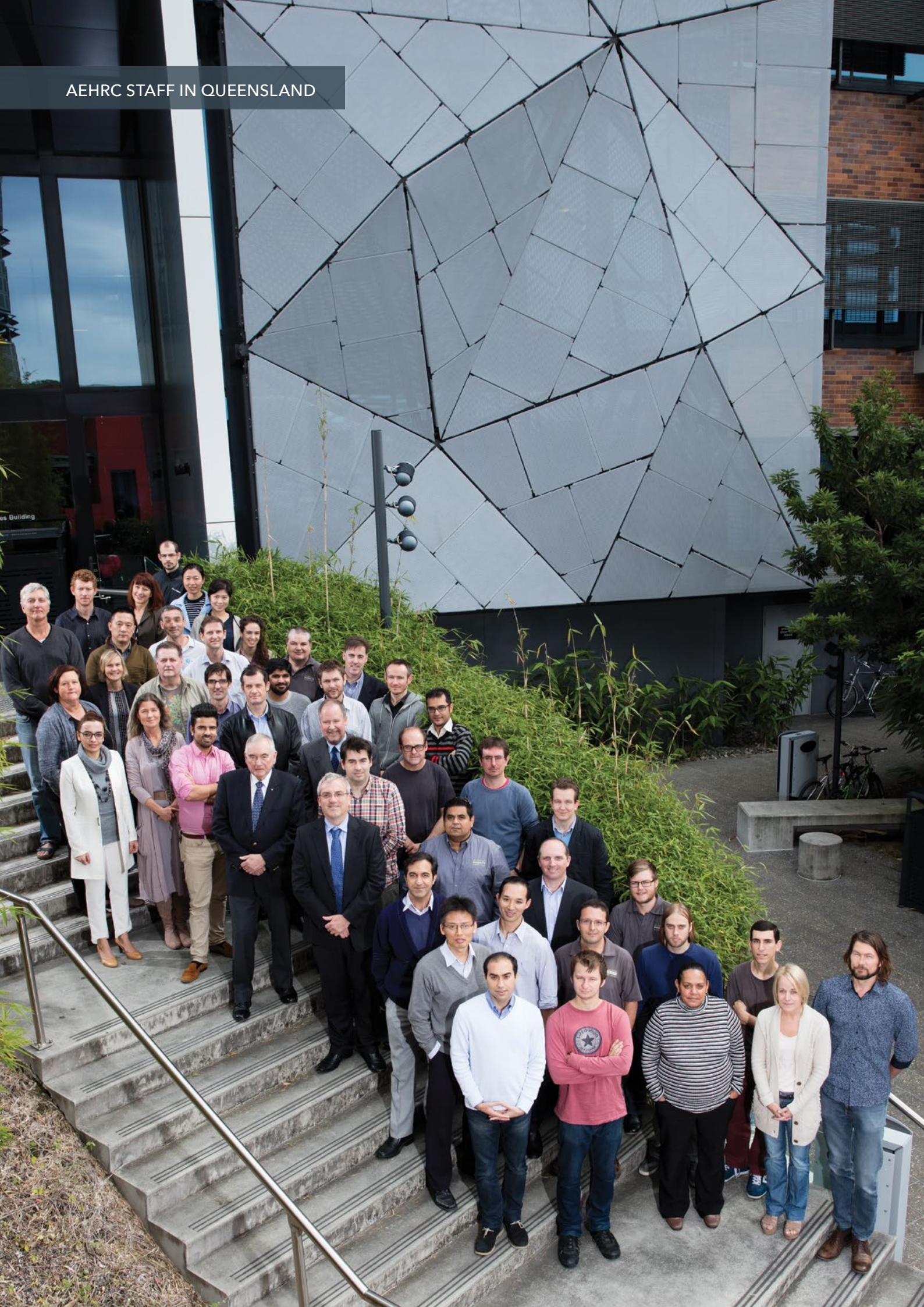
# ANNUAL REPORT

## 2015 / 2016

RESEARCH . DISCOVERY . INNOVATION  
POWERS HEALTH IN THE DIGITAL AGE



AEHRC STAFF IN QUEENSLAND



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# THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

A Partnership between CSIRO and the Queensland Government, The Australian e-Health Research Centre (AEHRC) is the leading national research facility applying information and communication technology to improve health service delivery for Australians. The Centre is an unincorporated joint venture between CSIRO and the Queensland Government.

Established in 2003 with initial funding from the Department of State Development and CSIRO, the partnership was extended in 2007 for a further 5 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 5 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.

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 (ATDRG) in Perth in conjunction with the Western Australia Department of Health. While the initial focus of this activity was on telemedicine and ocular imaging technologies the group has grown to include tele-medicine delivery for a wide range of conditions. Through further CSIRO in-kind contributions and other external funding the AEHRC now 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 multi-disciplinary team includes internationally prominent researchers, software engineers and doctoral students, dedicated to serving the needs of patients, clinicians and health service providers.

The Australian e-Health Research Centre is CSIRO's e-Health Research Program, conducting research across Health Informatics, Biomedical Informatics and Health Services.



## FOREWORD BY THE CHAIRMAN

After 8 years as Chairman I am pleased to see the Australian e-Health Research Centre continue to go from strength to strength. 2015/16 has been another excellent 12 months in delivering e-Health impacts and scientific excellence to our unincorporated joint venture partners, CSIRO and Queensland Health, and to our research partners and customers.

This year brought some significant achievements of which we should be particularly proud. The CardiHab spinout is taking our mobile-phone based cardiac rehabilitation program to a commercial market. The future of healthcare is very much about guided self-care in the community – and mobile phones are increasingly the natural tool to provide that guidance.

Our data analysis of the impact of the National Emergency Admission Target (NEAT) on standardised hospital mortality, published in the Medical Journal of Australia, has quickly become an exemplar of data driven policy making in healthcare. The increased capture of data in primary and secondary care indicates that data can drive many more policy decisions.

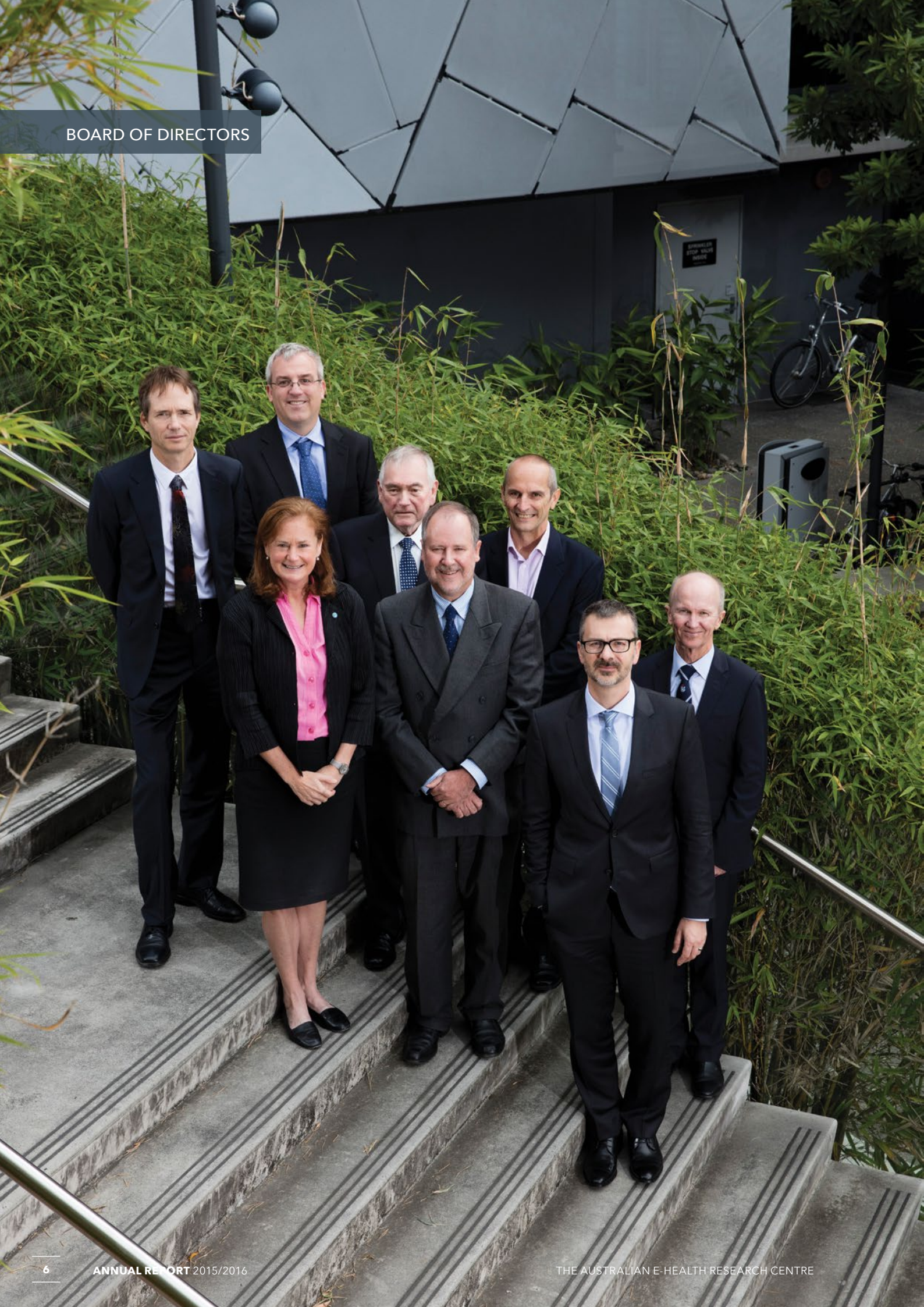
Meanwhile our technologies are supporting an increasing number of national services and trials. This year has seen more of our research be used in the delivery of health services – such as our terminology tools become part of Australia's digital health architecture. Across our health informatics, biomedical informatics and health services groups we are partnering with leading clinical researchers in numerous research trials, often funded through prestigious NH&MRC grants.

As I stand down as the Chair of the Board I would like to thank our joint venture partners and our customers and collaborators for their support for the continued growth of the AEHRC. Most importantly I'd like to thank the staff of the AEHRC. Our scientists and engineers, led in exemplary fashion by CEO David Hansen, have demonstrated continued dedication to making healthcare safer, more efficient, and of higher quality than it is now.

I have thoroughly enjoyed my involvement with the AEHRC and wish Richard Royle well as he takes on the role Chair. I know that the AEHRC has a long and bright future and that I leave it in capable hands.

**Prof Bruce Barraclough AO**  
Chairman, the Australian e-Health Research Centre

BOARD OF DIRECTORS



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# FOREWORD BY THE CEO

This year has been another year of growth for the Australian e-Health Research Centre. Over the past 12 months we have seen our staff numbers grow to 75 scientists and engineers as we have been successful in developing new business opportunities and research collaborations.

As well as working on the spinout of CardiHab, our health services group has developed a number of new mobile health research trials – in areas including Indigenous health, COPD, orthopedics and diabetes. These trials are being undertaken with our Qld Health collaborators as well as commercial entities and not-for-profit groups.

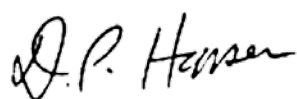
Our health informatics group has partnered with the new Australian Digital Health Agency to develop a National Clinical Terminology Service – which will be one of the foundational capabilities of Australia's national e-Health infrastructure. Many of our terminology tools and medical narrative processing tools are now finding new applications with Qld Health and other customers and collaborators. Our work in health data analytics is also growing – with new projects with Qld Health, the Victoria Department of Health and Human Services and commercial customers funded over the past 12 months.

Our Biomedical Informatics group – across medical imaging and bioinformatics – continues to increase our clinical and clinical research collaborations. Over the past 12 months the teams have continued to be successful in NH&MRC grants and delivering exciting science outcomes for our collaborators.

Our node in Perth, The Australian Tele-health Research and Development Group is our partnership with the Western Australian Department of Health. The team continues to develop innovative solutions for tele-medicine based health delivery – with new projects in wound care and dentistry.

The past 12 months has also seen the Australian e-Health Research Centre partner across the program with the new Genomics Health initiatives around Australia – including the Melbourne Genomics Health Alliance, the NH&MRC Australian Genomics Health Alliance and most recently the new Qld Genomics Health Alliance. These are exciting opportunities for all our scientists to be involved in Precision Medicine initiatives.

I would like to acknowledge the contribution that our Chair has made to the AEHRC. Bruce joined the AEHRC as Medical Director in 2007 and then became board chair in 2009. Bruce has shown a masterful ability to Chair the Board of the AEHRC and ensure that our joint venture partners are engaged and actively supporting the Centre's growth. Bruce has been a wonderful mentor for the CEO, particularly for me when I became CEO in 2011. Bruce's contribution to the AEHRC has been a significant factor in our success.



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**Dr David Hansen**  
Chief Executive Officer

# BOARD OF DIRECTORS

**Professor Bruce Barraclough AO,**  
*Outgoing Chair,  
the Australian e-Health  
Research Centre*

Prof Bruce Barraclough AO has a distinguished career in medicine with a particular focus on breast and endocrine surgery.

Amongst many professional activities, Prof Barraclough has served as the President of The International Society for Quality in Health Care, Chair of the Board of the NSW Clinical Excellence Commission, Chair of the Australian Council for Safety and Quality in Health Care, Medical Director of the Australian Cancer Network, a member of the NSW Health Care Advisory Council and Associate Dean (Clinical Strategy), University of Western Sydney Medical School.

Prof Barraclough is a Fellow of the Royal Australasian College of Surgeons, a Fellow of the American College of Surgeons and an Honorary Fellow, Royal College of Surgeons of England. He was formerly Dean of Education, Royal Australasian College of Surgeons.

In 2003, Bruce Barraclough was created an Officer in the Order of Australia for services to medicine as a surgeon, to medical education, particularly the development of high-level surgical training facilities, and to the community through fostering improvements in the delivery of safe, quality healthcare in Australia.

**Richard Royle**  
*Incoming Chair,  
the Australian e-Health  
Research Centre*

Richard has 35 years experience in the healthcare industry and has spent the past 10 years as Executive Director of UnitingCare Health in Queensland, incorporating 4 private not-for-profit hospitals totalling over 1,000 beds, and employing approximately 4,000 staff.

He is immediate past President of the Australian Private Hospitals Association and an Adjunct Professor at the University of Queensland and Queensland University of Technology in Health Management.

Richard has overseen the successful development and opening of Australia's first fully integrated digital hospital in Hervey Bay in 2014, and in 2013 undertook the role of chairing an independent review into the Personally Controlled Electronic Health Record on behalf of the Federal Government. He is now actively involved in establishing the new governing body for digital health in Australia.

**Dr Richard Ashby**  
*Chief Executive, Metro South  
Hospital and Health Service*

Dr Richard Ashby is the Chief Executive, Metro South Health and previously held the positions of Executive Director and Director of Medical Services at the Princess Alexandra Hospital in Brisbane. Dr Ashby is a former CIO of Queensland Health and is currently Senior Responsible Officer of the Queensland Digital Hospital Program. Dr Ashby has a long history in e-Health in Queensland and nationally, having sponsored or managed the implementation of several large systems including the Clinicians Knowledge Network. He has previously represented the Australian Medical Association on Standards Australia IT14, he is a Director of the Translational Research Institute, and the Australian Prostate Cancer Research Centre.

**Cathy Ford**

Cathy has more than 25 years' experience in the industry supporting organisations, executives and their teams through transformation activities that delivered sustained change.

As a Management and ICT Professional Cathy works with organisations to transform their business by developing strategies to make better use of people, information, systems and technology. Cathy delivers business value by acting as a change agent for organisations seeking to optimise their business whether that be through customer engagement, service improvement, organisational productivity and efficiency strategies or technology innovation.

Cathy has been acting in the role of Chief Digital Strategy Officer for eHealth Queensland for over a year. In this role she is responsible for leading the state towards a fully integrated healthcare system, supporting the ICT needs of the state's 16 Hospital and Health Services and the Department of Health.

### Colin McCrirk

Colin was initially appointed Chief Technology Officer for the Department of Health in January 2015 before being appointed to the Chief Executive/Chief Information Officer role for eHealth Queensland in November 2015. Prior to this Colin's career covers over thirty years of technology experience in a variety of different industries including banking, insurance, utilities and government departments. This includes executive leadership of large transformational projects and operational roles with distributed teams across Australia, India, China and the Philippines.

Colin has a bachelor of Mathematics, an MBA and is a graduate of the Australian Institute of Company Directors.

### Anita Hill

Dr Anita Hill is the Executive Director for Manufacturing, Food & Nutrition, Health & Biosecurity and CSIRO Services. She is an Office of the Chief Executive Science Leader with CSIRO. She is former Chief of CSIRO Process Science and Engineering. She is a Fellow of the Academy of Technological Sciences (ATSE) and former Chair of the Victorian Division, current member of the Advisory Boards of the Victorian Centre for Sustainable Chemical Manufacturing (VCSCM), Australian Institute for Bioengineering and Nanotechnology (AIBN University of Queensland), Australian eHealth Research Centre (AeHRC), Australian Centre of Excellence in Electro materials Science (ACES Uni Wollongong) and *Journal of Polymer Science* (editorial board).

Dr Hill was awarded a Bachelor of Engineering and a Doctor of Philosophy in Mechanical Engineering and Materials Science, both from Duke University, Durham, North Carolina, USA. Dr Hill lectured at Monash University before consulting for Materials Engineering and Technical Support Services prior to joining CSIRO. She has led research for Australian and international companies resulting in improved products and processes.

### Adrian Turner

Adrian Turner is the CEO of Data61 at CSIRO. Data61 is creating our data-driven future.

Adrian is a successful and influential Australian technology entrepreneur who has spent 18 years in Silicon Valley. Most recently he was Managing Director and Co-Founder of Borondi Group, a holding company focused on the intersection of pervasive computing, platform economics and traditionally conservative industries. Prior to this, Adrian was co-founder and CEO of smart phone and Internet of Things security company Mocana Corporation, had profit and loss responsibility for Philips Electronics connected devices infrastructure, and was Chairman of the Board for Australia's expat network, Advance.org. He was recently named co-Chair of the Cybersecurity Growth Centre, is a member of the Board of the Australian eHealth Research Centre and is also a member of the UTS: Business School Advisory Board.

He is regarded as a thought leader on entrepreneurialism, Internet of Things and the impact of network connectivity on business economics. He authored the eBook *BlueSky Mining – Building Australia's Next Billion Dollar Industries*. Adrian is a UTS graduate and has completed the Executive Program for Managing Growth Companies at Stanford University.

### ACKNOWLEDGE

**Stephen Ayre** – Executive Director, PAH-QEII Health Network

**Richard Symonds** – Minutes Secretary

**Kelly Tighe** – Finance Manager, CSIRO

### MEETINGS

Board Meetings for 2015/2016 were held as follows:

7th September 2015  
9th November 2015  
29th February 2016  
6th June 2016

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# MANAGEMENT & LEADERSHIP



DR DAVID HANSEN

## CEO, THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

David Hansen is CEO of the Australian e-Health Research Centre, a Research Program in the CSIRO Health and Biosecurity business. David leads an e-Health research portfolio developing information and communication technologies for the healthcare system. These projects across health informatics, biomedical informatics and health services research will underpin the e-health architecture in Australia.

Prior to joining CSIRO, David worked for LION bioscience Ltd in the UK, developing genomic data and tool integration software that was used to publish the first human genome and used at over 200 pharmaceutical and biotechnology companies and research institutes worldwide.



MICHAEL LAWLEY

## GROUP LEADER, HEALTH INFORMATICS

Dr Michael Lawley is a Senior Principal Research Scientist and Group Leader with the CSIRO Australian e-Health Research Centre, part of the Health & Biosecurity Flagship. Michael leads the Health Informatics Group with teams working on Health Data Semantics, Health Statistics, as well as a Software Engineering team.

He has deep expertise in Clinical Terminology and specifically large scale ontologies such as SNOMED CT. Technology developed by Michael and his team have produced technologies that have been licensed nationally and internationally by standards bodies, government organisations and SMEs.



OLIVIER SALVADO

## GROUP LEADER, BIOMEDICAL INFORMATICS

Dr Salvado is the group leader for the Biomedical Informatics group at the AEHRC. He is adjunct Professor at the University of Canberra, adjunct Associate Professor at the University of Queensland, and Honorary Research Fellow at the Florey Neuroscience Institute. His research interests include developing bio-informatics methods for large multi-scale clinical studies, Neuroimaging technologies, and investigating novel multi-modal clinical imaging biomarkers. Since 2009, he has been co-supervisor or assessor of 10 PhD students (2 current co-supervisions).

Dr Salvado has published over 70 original research papers cited more than 2700 times in highly-regarded journals including Lancet Neurology, JAMIA, Journal of Neuroscience, NeuroImage, PLoS One, Annals of Neurology, and Brain. Dr Salvado is the co-chair of the ISBI conference that will take place in Melbourne, Australia in 2017.



MOHAN KARUNANITHI

## GROUP LEADER, HEALTH SERVICES

Mohanraj Karunanithi leads the Health Services group at the AEHRC. Mohan has a doctorate in Biomedical Engineering, University of New South Wales. He has over 10 years of experience in cardiac research and 5 years of medical industries experience. At AEHRC, Mohan manages and coordinates research in ICT application in healthcare management and delivery of chronic diseases and aged care.



PROF. YOGESAN  
KANAGASINGAM

## DIRECTOR, AUSTRALIAN TELE-HEALTH RESEARCH AND DEVELOPMENT GROUP

Prof. Yogesan has developed medical technologies from bench to bed and one of his inventions is used by NASA in the International Space Station. He was the Australian of the Year finalist from WA (2015) and also WA Business Leader of the Year finalist in 2014 for his contribution to Medical Sciences and prevention of blindness. 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.

# 2016 ANNUAL COLLOQUIUM



Over 250 people attended Australian e-Health Research Centre annual e-Health Research Colloquium on the 16th March and with a great international keynote speaker and 11 other talks from our partners and staff.

Our keynote speaker, Doug Fridsma, gave a great overview of the US HITECH Act that provided \$30b to increase meaningful adoption of electronic medical records in the USA. The talk provided some great learnings for Australia in what was successful and what lessons were learnt.

The colloquium came less than 3 months after the PA Hospital went live with the Digital Hospital program. Michael Drahiem, Head of Clinical Informatics at PA Hospital gave an overview of the work involved in implementing such a large change program in a major tertiary hospital.

In the middle session we heard from Michael Lawley, David Bunker and Michael Bainbridge about the National Clinical Terminology Service (NCTS) that NEHTA and CSIRO have recently launched, including a demonstration of an iPhone medications app that uses the service. Two AEHRC scientists then gave talks about patient centric projects. Jill Freyne then talked about usability issues in developing health information technology and Dana Bradford gave a talk about how the Smarter Safer Homes platform might be used to detect early signs of health events such as strokes. The middle session ended with Olivier Salvado giving an overview of the AEHRC medical image analysis capability and Michael Breakspear from QIMR talking about how the AEHRC is partnering with QIMR in a new Alzheimer's disease study.



The final session saw 5 talks about AEHRC projects. Katherine Economides from the Royal Australasian College of Surgeons gave an overview of the RACS Morbidity Audit Logbook tool; Charlie Baker spoke about our liver imaging projects with PA Hospital, Tony Russell, from the PA Hospital spoke about a trial of mobile health for newly diagnosed type 2 diabetes patients; and Denis Bauer spoke about the suitability of genomic re-analysis replacing lab testing. The final talk was from Guido Zuccon from QUT about patient perceptions of searching the web for health information.

# NEWS AND AWARDS

<http://advance.qld.gov.au/innovation-movement/news-events/roundtable-event.aspx>

- AEHRC scientists have won a number of best paper awards at conferences over the past 12 months
  - At HIC 2015, Jill Freyne and Dana Bradford won the Branko Cesnik award for Best Scientific Paper with their paper "Designing technology for assessments of CALD patient".
  - Mahnoosh Kholghi, a PhD student at the Queensland University of Technology with the Australian e-Health Research Centre, won the Best Student Paper Award at the Australasian Language Technology Association (ALTA) Workshop 2015 for their paper on the "Analysis of Word Embeddings and Sequence Features for Clinical Information Extraction".
  - Lee Reid (post-grad) won an award (Summa Cum Laude Merit Award) for his work presented at a conference in Singapore "Motor Learning Induced Neuroplasticity, Revealed by fMRI-Guided Diffusion".
- PhD student Ashley Gillman was runner up in the University of Queensland Medical School Three Minute Thesis Competition in June 2016.
- AEHRC's Mobile Phone based Cardiac Rehabilitation program was in the Top 10 in the OzApp awards.
- On the national front Dana Bradford's previous work at the Queensland Brain Institute was recognised as one of the top 10 NH&MRC projects for 2015.
- Internationally, the FoodTrack platform, developed by Simon Gibson and Karen Harrap in the Heart Foundation project won the United Nation's INFOODS Success Stories Award 2015 for significant food composition achievements.
- Mohan Karunanithi was selected as Advanced Queensland Community Digital Champion- announced at the parliament by Leeanne Enoch MP, Minister for Innovation, Science and the Digital Economy, and Minister for Small Business on 17th March 2016.
- iAwards success! Donna Truran, Michael Lawley, Ming Zhang and our collaborators at the Princess Alexandra Hospital won a Qld and National iAward for the SnoMAP project.
- CSIRO recognition. AEHRC staff continued to be recognised by CSIRO. This includes
  - Denis Bauer for winning a Julius Award for exceptional mid-career scientists
  - Michael Lawley and the clinical terminology team for winning a CSIRO Health and Biosecurity Outstanding Collaboration Award
  - Aidan O'Brien won the CSIRO Health and Biosecurity Successful Student/Postdoc Award
- David Hansen's article in The Conversation "Healthcare's technology revolution means a boost for jobs in IT".



# RESEARCH PROGRAM

The Australian e-Health Research Centre focuses on three capability areas.



## HEALTH INFORMATICS

The introduction of electronic health and medical records, including the Federal 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.

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



## 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 the new medical technologies. The aim is to develop techniques to report and visualize complex biomedical information for clinical diagnosis and screening. This information can ensure that the diagnosis is precise and the treatment appropriate 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.



## 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 being placed by chronic disease and aged care. Our teams are currently trialling technologies to deliver health services through mobile health and tele-health technologies for diseases from eye diseases, cardiac diseases and diabetes to stroke and hip replacement patients.

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



# HEALTH INFORMATICS

## 2015/16 SCIENCE AND IMPACT HIGHLIGHTS

- The AEHRC, with Qld Health clinicians, undertook a nation-wide study of the impact of the National Emergency Access Target on in-hospital mortality. Published in the MJA, the results provide an evidence base for informing national policy around hospital performance targets.
- This year saw the adoption of the AEHRC clinical terminology server, Ontoserver, as the technology for Australia's National Clinical Terminology Service run by the Australian Digital Health Agency. A number of companies and organisations have already taken up Ontoserver licences to enable implementation of state of the art support for clinical terminology in their e-Health products. Ontoserver enables easier integration of standard terminologies into software products, removing one barrier to a truly interoperable health data ecosystem.



**MICHAEL LAWLEY**  
Health Informatics  
Group Leader

Australia's health care system faces many challenges. One is the increasing demand for clinical information to be shared between individual health practitioners, health care provider organisations and state/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 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.

We apply machine learning, natural language processing, formal logic, and statistical and simulation approaches to problems involving decision support, systems modelling and reporting.



**ANTHONY NGUYEN**  
Health Data Semantics  
Team Leader

Data is captured about patients in a number of different formats, electronic repositories and 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.

The Health Data Semantics team is focused on deriving value from electronic health data in terms of improving patient outcomes, and health system performance and productivity. The group does this by developing and applying machine learning, natural language processing, information retrieval and formal logic approaches to deliver and support meaningful data interoperability and analysis for decision support, analytics, modeling and reporting.



**RAJIV JAYASENA**  
Health Data Analytics  
Team Leader

Our work in this area supports acute hospitals by applying evidence-driven strategies to support improved health outcomes. For example, hospital overcrowding and timing of discharge are commonly linked to sub-optimal patient flow, poor quality of care, and unnecessary mortality. Consequently hospital services subscribe to theoretical targets for occupancy levels and discharge times. A better understanding of how occupancy levels and discharge times influence patient flow parameters, and more precise targets based on these, derived through modelling and simulation, would improve capacity management strategies and care outcomes.



**DEREK IRELAND**  
Health Data Engineering  
Team Leader

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

# PROJECTS

## CLINICAL TERMINOLOGY

Successful adoption of standard terminologies such as SNOMED CT and the Australian Medicines Terminology (AMT) is vital for the success of enabling patient data to move between clinical systems – and the new My Health Record system – 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 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.

### A NATIONAL CLINICAL TERMINOLOGY SERVICE

The AEHRC has worked with the Australian Digital Health Agency to deliver the National Clinical Terminology Service. Following success with the phase 1 project, the AEHRC's Ontoserver was selected to deliver this service via a nationally hosted service. Technology providers could also license Ontoserver free of charge for integration into their own health record solutions, with a syndicated service keeping the terminologies synchronised. 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; 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 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 2015/16 the team has been refining the implementation to ensure Ontoserver is enterprise class, closely engaged in the refinement of the Terminology Services part of the HL7 FHIR Specification, and engaging closely with State jurisdictions and the vendor community through a series of very successful Connectathons and workshops to ensure that the resulting service delivers what is needed.

Already several Health IT providers and State health departments have become early adopters prior to the service going live in September 2016.

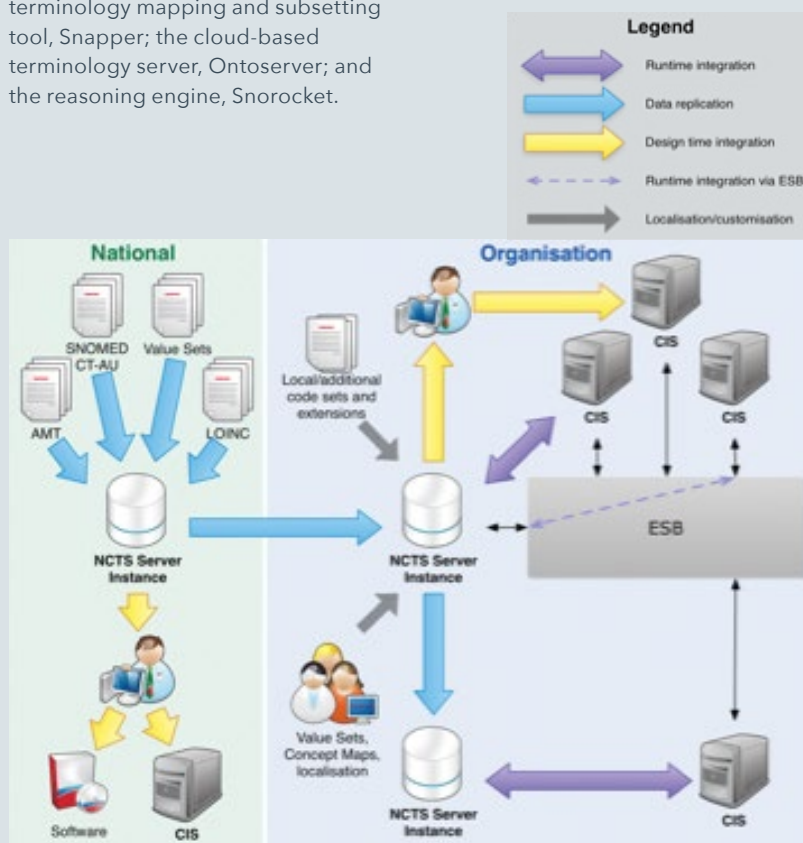


Figure 1. High-level architecture of the National Clinical Terminology Service (NCTS)

## CLINICAL TERMINOLOGY *(continued)*

### SNOMED CT IN THE QLD DIGITAL HOSPITAL PROJECT

The Queensland Digital Hospital Project is introducing the SNOMED CT terminology as part of the implementation of an integrated Electronic Medical Record. As part of this project the AEHRC has 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.

The first project dealt with the problem of continued reporting of ED non-admitted patients after the switch from use of ICD 10 AM to SNOMED CT. The result of this was a tool, snoMAP. The snoMAP tool extends coverage of SNOMED CT from a relatively small subset of Clinical Findings to all relevant codes in the hierarchy. The goal was to re-purpose the original SNOMED CT-encoded patient data and maintain its truth value to ensure it complies with, and qualifies, for Activity Based Funding.

The second project was to evaluate SNOMED CT data quality as affected by specific user interface elements. Escargot provides a visualisation of refinements to the display text of SNOMED CT diagnosis codes in the patient record. By performing some simple analysis, these changes can be categorised to indicate whether a significant change in meaning is indicated and thus can be used to highlight potential data quality problems. Preliminary results show that most changes are refinements to the code's meaning.

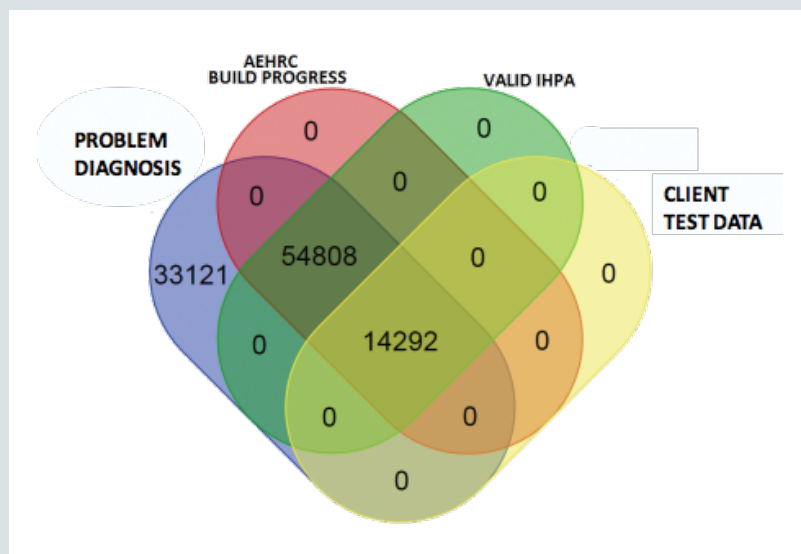


Figure 2. Ensuring SNOMED CT encoded patient data complies with, and qualifies for, Activity Based Funding

### PROJECT 3 RACS MALT GOES SNOMED CT-NATIVE

In 2015/16 the AEHRC continued our collaboration with the Royal Australasian College of Surgeons (RACS) to successfully transition their Morbidity Audit Logbook Tool (MALT) from ad-hoc terminology to using SNOMED CT-AU procedure codes natively. This includes the development and maintenance of aggregation maps to support ongoing reporting processes from the MALT data. We are now working with RACS to migrate them to an NCTS-based deployment of Ontoserver using FHIR-based valueset and map artefacts.

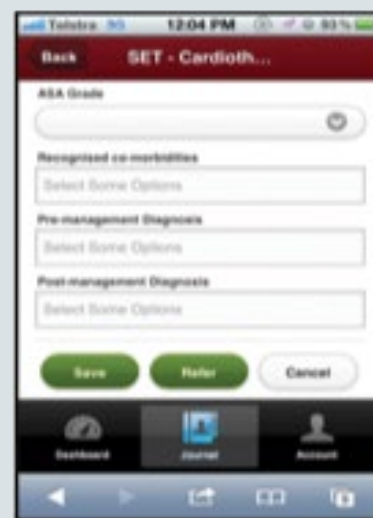


Figure 3. Mobile version of RACS MALT, SNOMED CT enabled via Ontoserver

**KEY COLLABORATORS:**

- Australian Digital Health Agency/National eHealth Transition Authority
- Royal Australasian College of Surgeons
- Princess Alexandra Hospital, Metro South HHS
- Australian Genomics Health Alliance

**PROJECT HIGHLIGHTS FOR 2015/16:**

- Shrimp is the go-to browser for SNOMED CT-AU
- Delivery of Ontoserver V4 for the NCTS with native FHIR APIs and syndication support
- Contribution to the refinement of the HL7 FHIR Terminology Services API standard
- First full implementation of the IHTSDO's Expression Constraint Language
- Complete rewrite of Snapper to work with FHIR and run in a web browser as a cloud-based app
- Impact of the snoMAP tool as it has been taken up at additional sites throughout Queensland

**PROJECT AIMS FOR 2016/17:**

- Investigate models to support reasoning across modular and multi-versioned ontologies
- Develop enhanced algorithms for automated analysis of terminology quality metrics to improve data quality
- Enhance support for OWL-based ontologies to support genomics projects
- Extend our automated techniques for developing aggregation-based maps for reporting and data analytics
- Build on the successful rollout of Ontoserver as the NCTS terminology server platform-of-choice through international adoption and licensing

## MEDICAL TEXT ANALYTICS



The majority of health data is recorded in unstructured free-text; clinical examination reports, nursing notes, discharge summaries, death certificates are just some examples. This data contains information that is valuable for clinical decision support and secondary use such as for population health monitoring and reporting. However, its clinical importance and large volume hinders the manual analysis of such data.

The medical text analytics team is developing and applying advanced natural language processing, information retrieval, and machine learning techniques, along with standard clinical terminology, to overcome the problems of understanding and reasoning with clinical data.

Our solutions have been developed in partnership with healthcare practitioners from Cancer Registries, hospital radiology and emergency medicine departments. Working with health industry stakeholders allows our medical text analytics solutions to leverage the wealth of clinical narrative reports and aid in decision support and reporting.

### AUTOMATING CANCER REGISTRY TASKS

Cancer notifications to the Cancer Registry are currently paper based and the incidence of cancers is increasing with the number of new cancer cases. A growing backlog is delaying the delivery of more timely cancer information due to the extent of manual processing and an out-dated information collection system. This highlights the need for introducing new technologies to assist with automating cancer registry processes.

In partnership with the Queensland Cancer Control Analysis Team, Queensland Health, we are providing semantic medical text analytic services to automatically read and analyse the free-text contents of pathology HL7 messages for cancer notifications, synoptic reporting and cancer staging. This information provides the capacity to support key activities such as cancer monitoring, health service planning and research.

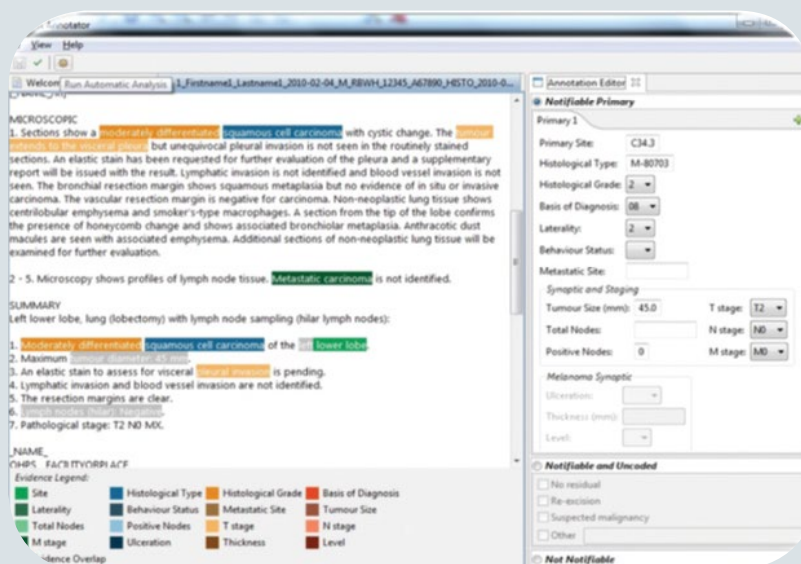


Figure 1. The Medtex software can process narrative pathology reports and generates structured data to aid clinical coders in cancer abstraction tasks.

## CHECKING MEDICAL RECORDS TO PREVENT MISSED DIAGNOSES

The checking of radiology and pathology reports to ensure abnormalities are not missed and that patients receive appropriate follow-up once discharged from the Emergency Department (ED) is an essential but laborious task.

In partnership with the Royal Brisbane and Women Hospital, Gold Coast University Hospital and The Prince Charles Hospital Emergency and Medicine Departments, we have developed systems to reliably identify abnormal or positive results from radiology and pathology reports, respectively, and link these with patients disposition as recorded in the Emergency Department Information System to provide decision support to the, currently manual, checking process.

## MEDICAL RECORD SEARCH & ANALYTICS

Search technologies are critical to enable clinical staff to rapidly and effectively access patient information contained in free-text medical records. Medical search is challenging as it suffers from the semantic gap problem: the mismatch between the raw data and the way a human being 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 medical record searching and analytics using text, concepts, annotations, and SNOMED CT subsumption and relation querying.

In partnership with the Radiology Department of the Princess Alexandra Hospital, we developed a system designated specifically for search, retrieval and analysis of free-text radiology reports. This allows radiologists to perform both individual case retrieval and data exploration for research purposes.

## DIAGNOSIS CODING FROM ELECTRONIC MEDICAL RECORDS

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 judgments from clinical coders, and the effort required for information abstraction is extremely labour and time intensive and prone to human errors.

In partnership with Gold Coast University Hospital and Telstra Health, we have investigated the feasibility of automating the diagnosis coding (ICD-10) process from hospital progress notes.

Promising results were achieved when compared to what was projected as possible from a diagnosis code validation study.

In addition, in partnership with the Centre for Epidemiology and Evidence within NSW Ministry of Health and the Cancer Institute of NSW, we developed systems to automatically enhance the use of death data to provide up-to-date information on deaths of high public health relevance in the community. A high quality method to automatically code the cause of death (ICD-10) from text information contained in death certificates was developed.

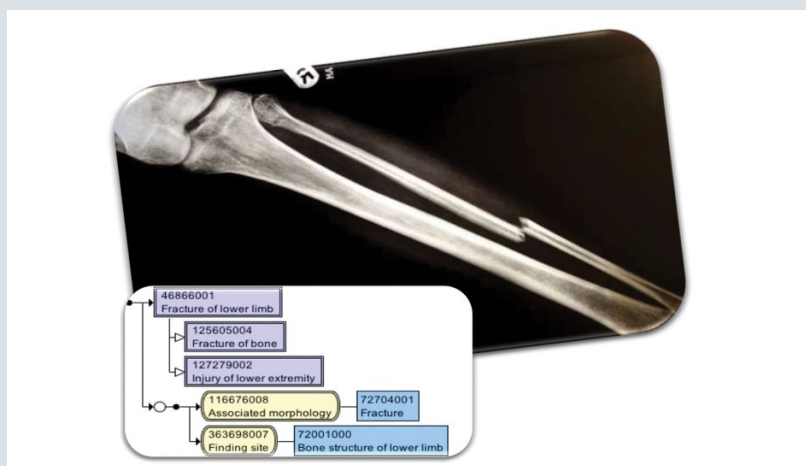


Figure 2. Medtex uses SNOMED CT, the internationally defined set of clinical terms, to unify language of medical records.

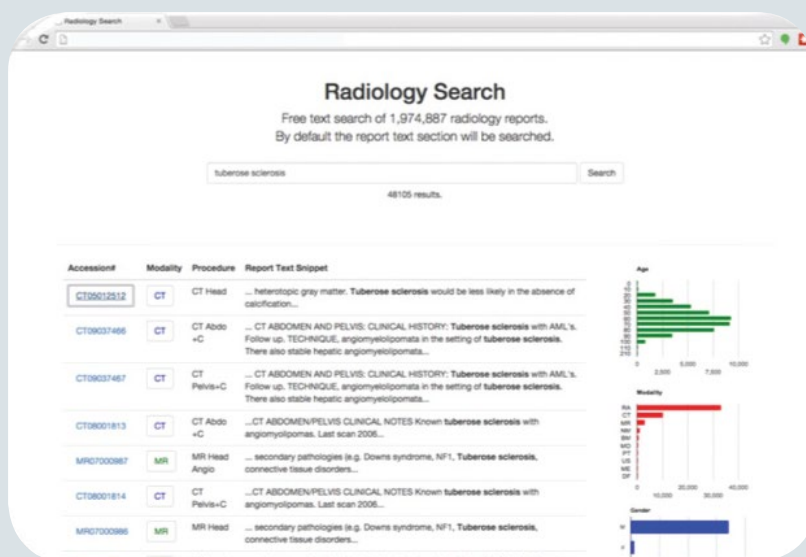


Figure 3. A search and analysis engine for free-text radiology reports.

## MEDICAL TEXT ANALYTICS *(continued)*

### 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, Gold Coast University Hospital
- Information Management and Technology, Gold Coast University Hospital
- Department of Radiology, Princess Alexandra Hospital
- Peter MacCallum Cancer Centre, Victoria
- Royal College of Pathologists of Australasia
- NPS MedicineWise
- Sanofi-Aventis Australia
- Telstra Health

### PROJECT HIGHLIGHTS FOR 2015/16:

- Developed a new high throughput computational framework for Medtex - to support faster text processing and analytics of large-scale clinical narrative reports.
- Deployed the new Medtex within Queensland Health to process and analyse live pathology feeds for cancer notifications from across the State of Queensland.
- Initial trial completed at The Prince Charles Hospital to reconcile microbiology pathology reports and Emergency Department discharge summaries to flag patients with positive test results. This can provide decision support to the current, manual, checking process.
- Medtex adapted to automatically code diagnoses (ICD-10-AM) from text information contained in progress notes. A high level of agreement was achieved when compared to what was projected as possible from a diagnosis code validation study.

### PROJECT AIMS FOR 2016/17:

- Investigate and develop new machine learning techniques and algorithms based on deep learning to improve clinical language understanding.
- Automatically abstract important clinical indicators for cancers to extend the cancer stage and synoptic reporting capabilities within Queensland Health.
- Develop medical record checking decision support application for clinical interaction.
- Extend the medical text search and analytic technology solutions to other health applications and report types.

### PHD STUDENT PROFILE

**Name: HAMED HASSANZADEH**

**Completed: June 2016**

**The Australian e-Health Research Centre Top-Up Scholarship  
University of Queensland**

**TOPIC: A FRAMEWORK FOR DEVELOPING KNOWLEDGE BASES OF SCIENTIFIC ARTEFACTS IN THE BIOMEDICAL DOMAIN**

The increase in publication of biomedical papers presents search engines with the challenge of identifying artefacts such as hypothesis, observations and interventions.

The framework described in this thesis has the potential to transform large corpuses of unstructured text into an enriched, consolidated and linked network of scientific artefacts for use in Evidence Based Medicine (EBM). The technology developed transforms unstructured publications into structured, consolidated, pertinent knowledge. The approach proposed employs novel, sets of low-level features to uniquely identify key scientific information in EBM, and enable knowledge extraction and retrieval. This then led to the automatic creation of networks of scientific artefacts attained through consolidating and linking scientific artefacts using Linked Data approaches.

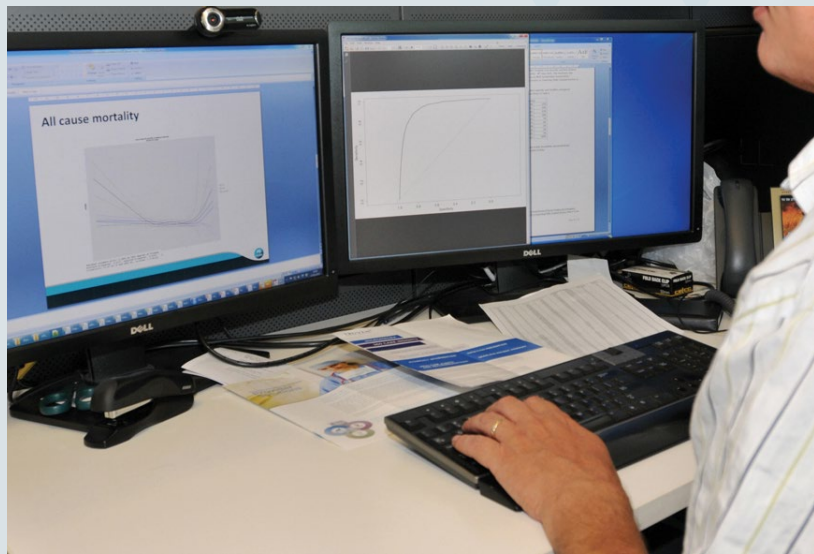
The resulting Knowledge Base has the potential to enable clinicians to quickly gain a broad and deep understanding of the current state of evidence related to a medical topic. It enables them to more easily compare the results of similar or related studies and to apply informed reasoning. Consequently, instead of searching and reading numerous abstracts in order to make a decision, clinicians can quickly access key statements that summarize previous clinical studies, through an easily navigable knowledge base of scientific artefact.

## HEALTH DATA ANALYTICS

### PROJECT DESCRIPTION

State health systems in Australia are being pushed to perform better and this work assists our state government partners achieve this, by improving the capacity of governments to plan and manage their resources. The health data analytics team is helping hospitals by performing system evaluation to help meet patient flow performance targets, whilst solving the challenge of overcrowding and system bottlenecks. The team undertakes patient flow modelling research with our partner hospitals, where analytics, optimisation and operational decision support tools can help hospitals obtain a better understanding of what they could do to meet flow related performance targets.

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. The Health Data Analytics team include several statisticians and research scientists to ensure statistical rigour in every analysis.



### GENERATING AN EVIDENCE BASE FOR INFORMING NATIONAL POLICY AROUND HOSPITAL PERFORMANCE TARGETS

In 2015, the CSIRO Health Data Analytics team undertook a formal evidence based scientific analysis to inform policy around the National Emergency Access Target (NEAT), examining:

- The evidence around the then current 90% target and 4 hour discharge parameters
- The potential value of differentiating between admitted and discharged patient targets
- The relationship between NEAT and mortality.

This study involved identifying the relationship between NEAT and Hospital Standardised Mortality Ratio using an extract initially covering 168 public hospitals from Australia and New Zealand but subsequently filtered to 59 Australian hospitals for a four-year analysis period. There was a need to determine optimal NEAT levels which maximise the benefits of decongesting EDs while minimising the potential harms of rushed and suboptimal management of acutely ill patients. The study found that in-hospital mortality of emergency admissions declines as NEAT compliance rates increase up to a point, beyond which there is no evidence of any reduction in mortality. The work also advocated continued measurement of NEAT for all patients presenting at hospital emergency departments and separately for those patients who require admission.

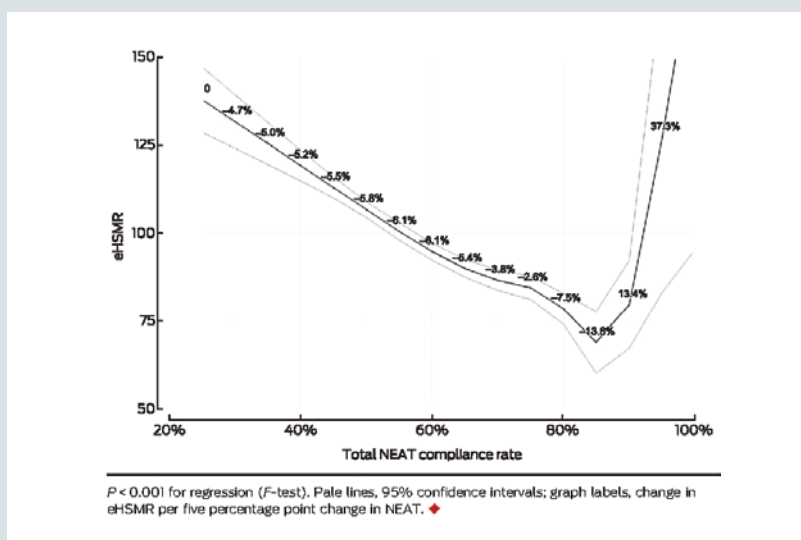


Figure 1. Modelling the relationship between emergency access target compliance and in-hospital mortality

## HEALTH DATA ANALYTICS *(continued)*

### PLANNING FOR WINTER: MEETING DEMAND AND OPTIMISING SERVICE DELIVERY

In 2015/2016 the team were asked to quantify the impact of winter on state-wide hospital bed planning in Queensland in order to form the basis of 2016 winter bed plans for all of Queensland Hospital and Health Services. The study identified the response of the health system to recent growth in demand, measured the impact on particular patient cohorts such as patients with influenza-like illness, and employed predictive modelling to identify critical dates when demand was likely to exceed capacity. The work aligns with the need for health sector policy to be based on evidence and also demonstrates the team's understanding of the challenges in delivering public healthcare.

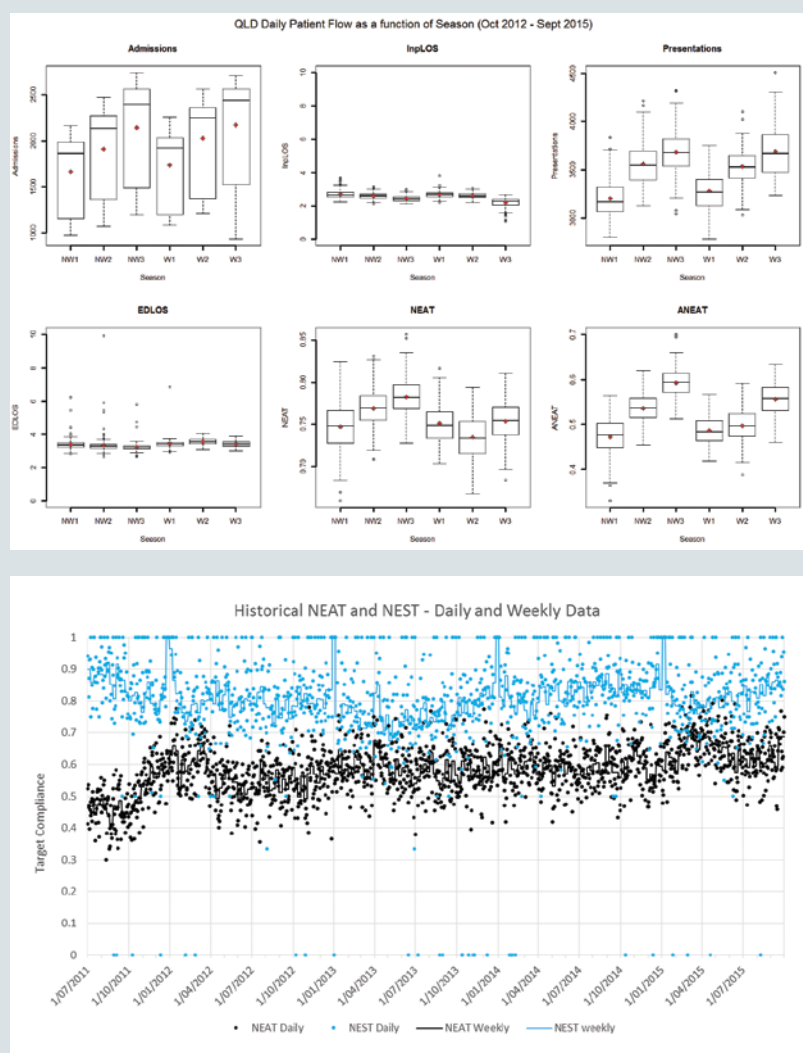


Figure 2. Exploring the relationship between the two main flow-related KPIs for Australian public hospitals.

### EVIDENCE-BASED KEY PERFORMANCE INDICATORS AND IMPROVING HOSPITAL PERFORMANCE

In 2015/2016, the team delivered an analytical project funded by the federal Department of Health at Austin Health Victoria. The study involved the analysis of patient flow at Austin Hospital and is believed to be the first study to explore the relationship between the two main flow-related KPIs for Australian public hospitals NEAT (National Emergency Access Target) and NEST (National Elective Surgery Target). The findings are of interest to hospital administrators nationally in having evidence-based flow KPIs and discovering actionable strategies to further improve flow performance.

The study identified that Hospital Initiated Cancellations are a more instantaneous measure of capacity challenges than NEST compliance, and recommended the introduction of a new metric for ED performance (measuring the magnitude of NEAT breaches in addition to NEAT compliance rates).

The study also involved the analysis of patient journeys through a hospital ED and identified statistically significant differences between hour of day, departure status, triage category and diagnosis in delays within these ED journey, and quantified the improvement in flow performance resulting from reducing various delays in a patient's journey through ED.

The work resulted in a better understanding of access performance and flow bottlenecks, to inform capacity management strategies and ultimately improve care outcomes.

## IDENTIFICATION OF CLINICAL OUTLIERS

In 2015/2016, the team developed a web-based software tool for use by front line health staff to interrogate clinical and financial data to aid in continuous operational improvement. This work was funded by the federal Department of Health and deployed at The Alfred Hospital Victoria. The deployed tool enables a user to visualise the cost of delivering hospital services, and to identify patients whose cost of care is more and less than expected (i.e. outside the normal range). This information can be used to identify how the cost of expensive care can be minimised and patients who are likely to be outliers can be identified early so interventions can be made to reduce the cost.

This approach is quite novel with no similar approaches currently being used in Australia. High-dimensional data is visualised using parallel coordinates, where numerous vertical axes are arranged side-by-side and polylines are drawn intersecting each axis that represent individual records for a patient.

The project is unique in the inclusion of statistical algorithms to reduce the number of dimensions that need to be visualised while still retaining the essential features of individual patient records. This technique, known as principal component analysis, effectively summarises many variables into one or two dimensions.

This tool is useful to all hospitals and clinicians across Australia in increasing efficiency and reducing costs. The parallel coordinate functionality is also important in other domains where correlations between multiple variables need to be revealed and is particularly useful in identifying which conditions correlate highly to a particular outcome. These techniques also have application where there is a need to monitor system performance, such as energy monitoring, project management or IT performance.

## PROJECT 5 - ANALYSIS OF PATIENT JOURNEYS THROUGHOUT HOSPITAL

This work quantified delays at various waypoints in a patient's journey through hospital across a multi-site setting. The team built simulation models to determine the impact of reducing each process delay on flow efficiency, and recommended specific bottlenecks associated with the greatest improvement on flow-related Key Performance Indicators.

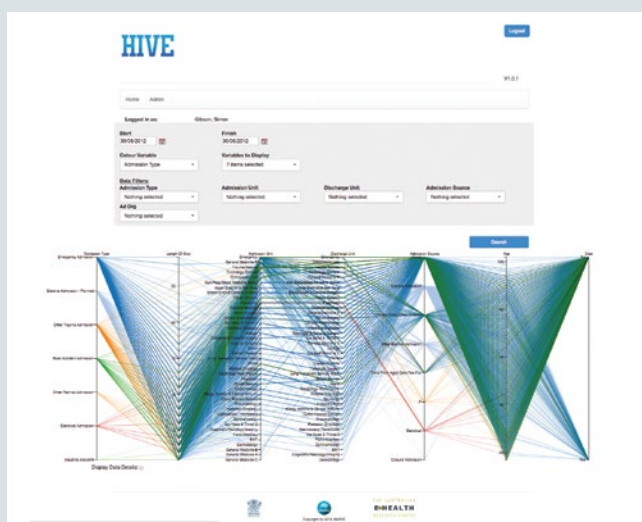


Figure 3. Visualising high-dimensional data using parallel coordinates to identify clinical outliers

## HEALTH DATA ANALYTICS *(continued)*

### COLLABORATORS:

- Federal Department of Health
- Austin Health
- Alfred Health
- 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
- Health IQ/Telstra Health

### PROJECT HIGHLIGHTS FOR 2015/16:

- Presentation of NEAT-mortality results to the Australian Health Ministers' Advisory Council (AHMAC) via its Hospitals Principal Committee meetings and adjustment of NEAT targets within Queensland based on the results.
- Establishing a novel method to evaluate clinical trials in real-time and evaluate surgery survival rates of surgeons or hospitals (a new application of risk adjustment, traditionally applied in monitoring surgery performance).

### PROJECT AIMS FOR 2016/17:

- Identifying chronic disease patients with high risk of hospital readmission.
- Improving the efficiency of hospital operating theatres.
- Characterising where variation in after-hours healthcare delivery may be impacting on clinical outcomes.

### PHD STUDENT PROFILE

**Name:** Zahra Shahabi Kargar

**Completed:** March 2016

**Griffith University**

**The Australian e-Health Research Centre (PhD Top-up Scholarship)**

As the hospital largest revenue and cost centre, operating rooms are of pivotal importance to the hospitals. Any improvement of surgery delivery systems is particularly important for hospitals. Improving operating room scheduling can deliver a significant improvement in utilisation key hospital infrastructure. Motivated by this need, Zahra collaborated with the Gold Coast Hospital and her thesis, entitled "Intelligent Scheduling for Hospital Operating Rooms", explores the delivery of improvements to operating room scheduling processes, particularly in Australian public hospitals.

A summary of the main contributions of this thesis are as follows:

- A novel methodology for scheduling operating rooms under uncertainty addressing demand uncertainty and procedure duration uncertainty in the scheduling system.
- A new algorithm for solving large scale stochastic combinatorial optimisation problems, enabling fast execution of the algorithm.
- Development and validation of a prediction algorithms for estimating surgery duration using four years of administrative and peri-operative data from the case study hospital.

## HEALTH DATA ENGINEERING

### PROJECT DESCRIPTION

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

Over the past 12 months the team have continued to develop our MoTER 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 MedText medical narrative processing software and developed FHIR based resources for use across our projects. The team also continue to support number of clinical trials with various Clinical Trial software packages.

### MOTER CHRONIC DISEASE 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. The engineering team manage a common framework to deliver these projects, attempting to maximise reuse while not hindering innovation, known as the MoTER Platform. The platform consists of iOS, Android native applications and a Web Portal for clinicians to review the collected data.

### AEHRC ON FHIR

Following the very successful FHIR mini Connectathon in March 2015, the team has been developing their FHIR knowledge and exploring opportunities to deploy FHIR in existing and new projects.

Activities included using the Medications Resource to represent medications from the Australian Medicines Terminology, experimenting with the use of FHIR ConceptMaps for MedText, and an investigation into the use of FHIR to represent and exchange clinical trials data, both as a view of ODM / CDISC data, and natively. This latter work is particularly timely as it aligns closely with the introduction of the PlanDefinition Resource as part of the latest draft version of FHIR due out at the end of the year.

### CLINICAL TRIAL SUPPORT

The engineering team provide support for clinical trial data management systems like REDCap and OpenClinica as well as custom data collection solutions.



# BIOMEDICAL INFORMATICS

## 2015/16 SCIENCE AND IMPACT HIGHLIGHTS

- This year our scientists were successful with chief investigators in 5 NHMRC grants. The successful grants included 2 NHMRC Dementia Team Grants and the NHMRC Australian Genomics Health Alliance.
- Our continuing contribution to Alzheimer's disease research has shown that vascular burden is a co-morbidity in Alzheimer's disease, allowing a better understanding of dementia. Those along with other important contributions were published in several manuscripts in high impact factor journals, including the Lancet Neurology (IF22). Overall our scientists have published a record number of publications this year with more than 50 journal manuscripts published.
- We have launched a cloud based clinical imaging research platform to automatically process PET and MRI scans to produce quantitative radiology reports. Currently there are two reports publicly available (atrophy from MRI and tracer uptake from PET). Those tools are processing 1000 scans for the AIBL study in addition to more than 350 PET scans from 20 external centers. Other reporting tools are under development ranging from personalized risk factor using genomics, to cerebral palsy assessment using advanced MRI technologies.
- Our clinical imaging team, in collaboration with the Calvary Mater Newcastle Hospital, is taking part in the first international multi-center prospective trial for MRI-alone external beam radiation therapy for localized prostate cancer. This follows on from two successful retrospective trials involving eighty men.
- We have continued to transfer our technology for commercial use, with our MRI based cartilage quantification technologies under evaluation at multiple clinical centers worldwide.



**OLIVIER SALVADO**  
Biomedical Informatics Group Leader

Our Biomedical Informatics research develops innovative medical technologies for the discovery and communication of meaningful patterns in biomedical data. Especially valuable in areas rich with recorded information such as medical images or genomics, these technologies rely on the simultaneous application of statistics, computer programming, and applied mathematics. The group also develops techniques to report and visualize complex biomedical information for clinical diagnosis and screening and to communicate insights to clinicians and clinical researchers.



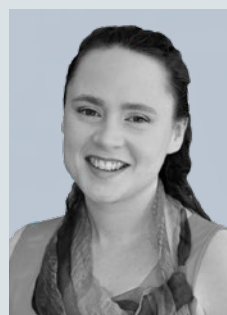
**JURGEN FRIPP**  
Medical Image Analysis Team Leader

Our medical image analysis is leading a paradigm shift in radiology from qualitative to (semi-) quantitative imaging and a new generation of "imaging biomarkers". Our technology uses turns images into information which can be used to improve diagnostic and screening tools, provide new insights and reduce healthcare costs.



**STEPHEN ROSE**  
Clinical Imaging Team Leader

Our clinical imaging research optimises the identification of injury, pathology and treatment response using advanced medical imaging technology. This involves developing novel imaging techniques and translating those techniques into the clinical environment to improve patient management and outcome and provide efficient hospital workflows.



**DENIS BAUER**  
Transformational Bioinformatics Team Leader

Our transformational bioinformatics 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.



**JAMES DOECKE**  
Biostatistics Team Leader

Behind every large scientific finding seen in the newspaper, on the web, or in scientific journals is a team of statisticians working to answer the biological questions posed by leading scientists today. Our team of statisticians here at CSIRO Health and Biosecurity, Biomedical Informatics are well placed to analyse biomedical data with the view to interpret some of the world's most important medical research questions.

# PROJECTS

## MEDICAL IMAGE ANALYTICS

The medical image analytics team's primary goal is automating the extraction of quantitative imaging biomarkers. Imaging biomarkers are features that are relevant to a patient's diagnosis. For instance, the size of a lesions measured from an MRI or PET scan can be used to provide a potential biomarker of disease severity. This involves research and development in both informatics and analytics.

One example is CapAIBL (Computational Analysis of PET from AIBL), which performs quantitative PET measurements without the need of acquiring an additional MRI. This information is then provided as a quantitative clinical report (designed in collaboration with our clinical partners, Austin Health in Melbourne).

### IMAGING MARKERS FOR NEURO-DEGENERATIVE DISEASES

Neurodegenerative diseases, refer to a group of age-related brain illnesses that result in progressive loss of brain tissue and cognitive decline. Early detection is now recognized as the critical path to effective treatment for various forms of neurodegenerative diseases including Alzheimer's disease, as it may allow interventions prior to widespread tissue loss. In collaboration with the researchers of Austin Health, Florey Institute of Neuroscience, McCusker Alzheimer's Research Foundation (MARF) and Edith Cowan University (ECU) we have been involved in the Australian Imaging and Biomarker and Lifestyle study that has provided strong evidence that Amyloid beta plaque accumulation commences 10-20 years before clinical symptoms. In addition, recent work has found that cortical atrophy is locally associated with tau neurofibrillary tangles accumulation.

As part of this research, our team has been providing capabilities to

- a. Optimise MRI based biomarkers (hippocampal volume, cortical atrophy) for detection and prediction.
- b. Optimise PET based biomarkers ( $\beta$ -amyloid, Tau and glucose metabolism) for earlier detection and differential diagnosis.

An example of the results provided by our team can be seen in Figure 1. Our team's research involvement is on the processing and analysis of the acquired MRI and PET images, as well as the development of software tools and platform. Its research enables to establish link between image-based markers and active research fields of biomarker discovery, genetics, neuropsychology, and life style studies into Alzheimer's disease.

### IRON AND OTHER ADVANCED IMAGING MARKERS

Recent studies have demonstrated that iron burden of the brain (reflected by CSF ferritin levels) has an impact on longitudinal (7 years) outcomes of Alzheimer's disease (cognition, brain atrophy) similar in magnitude to the more established biomarkers of the disease (e.g. CSF tau and A $\beta$ ). In collaboration with the CRC for Mental Health and the Florey Institute of Neuroscience, we are using advanced MRI to improve our understanding of the role of iron in healthy ageing and Alzheimer's disease.

For this research, the two ultra high field MRI (7T) machines installed in Australia (University of Melbourne and University of Queensland) are used to perform iron quantification using techniques like quantitative susceptibility mapping (QSM, Figure 2). In addition, the higher field strength can also be leveraged to increase image resolution and reveal subtle anatomical structures that would not be visible on clinical MR scanners, such as the subparts of the hippocampus.

## MEDICAL IMAGE ANALYTICS *(continued)*

### IMAGING MARKERS FOR OSTEOARTHRITIS

Osteoarthritis (OA) is a joint disease that is characterized by breakdown of joint cartilage and underlying bone. Traumatic injuries, such as a tear of the anterior cruciate ligament (ACL) increases the risk of developing Osteoarthritis and provide a targeted way to investigate early pathophysiological changes in cartilage and intervene in a disease process. Our current research involves developing image processing techniques that can be used to improve the clinical picture of the pathophysiological processes preceding the development of Osteoarthritis (OA). In collaboration with the University of Queensland, Siemens Healthcare and the Steadman Philippon Research Institute, we are using advanced MRI to extract early markers of cartilage damage (eg. Figure 3 shows left: collagen structure, water content and right glycosaminoglycans (GAG) content) on a cohort of ACL and labral tear patients.

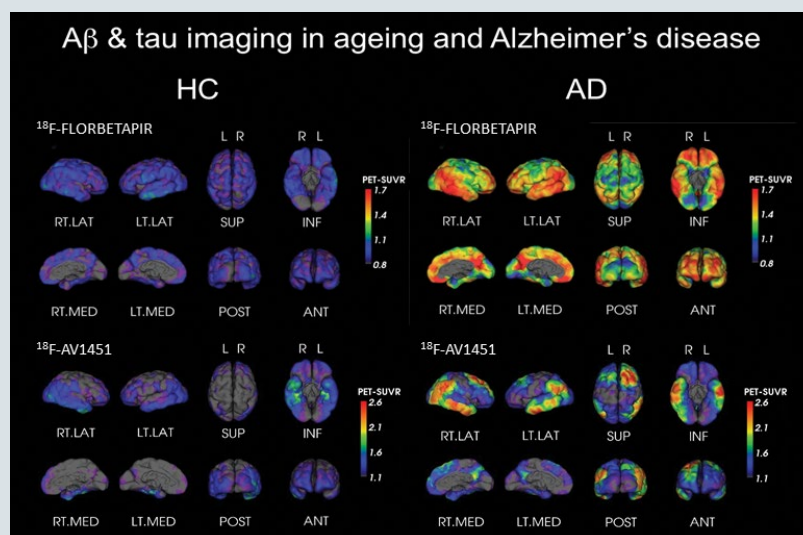


Figure 1. Amyloid and tau surface projections of a healthy elderly subject with no amyloid and tau uptake and a typical AD subject with high amyloid and tau uptake. The figure also illustrates the different pattern of amyloid and tau deposition in AD. (adapted figure from Villemagne)

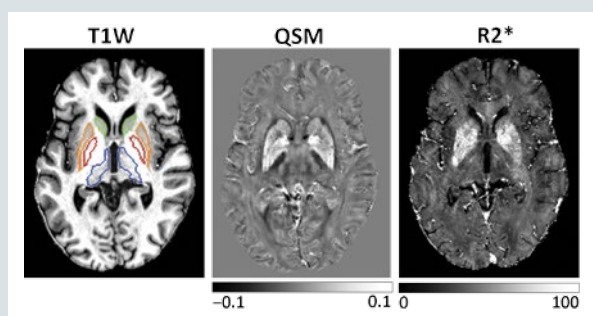


Figure 2. Images from a 2D cross-section of T1-weighted, quantitative susceptibility map (QSM) and R2\* (1/T2\*) of a healthy elderly female subject (72 years-old) at 7T (Acquired at the Center of Advanced Imaging, University of Queensland). Subcortical structures including globus pallidus (red), putamen (orange), caudate (green), and thalamus (blue) are enclosed by contours. Increased tissue iron level associated with neurodegeneration and aging has been reported particularly in the subcortical regions. The R2\* and QSM MR modalities are the most sensitive surrogate marker for iron in brain tissue.

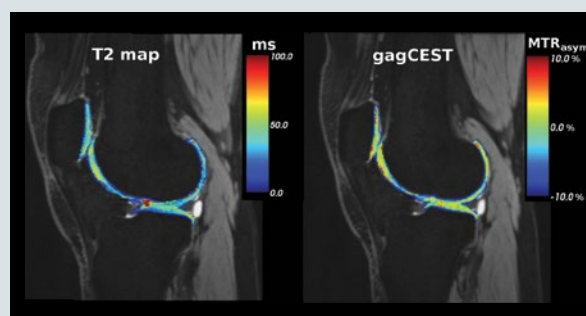


Figure 3. Example knee MRI scan (Acquired at the Herston Imaging Research Facility, Royal Brisbane and Women's Hospital). Two MRI protocols describing tissue biochemical properties (left: T2 relaxation time in milliseconds, right: gagCEST signal as percentage asymmetry of the magnetisation transfer ratio) are visualised in regions corresponding to the knee cartilage. Distribution of biochemical MRI signal can be used for quantitative assessment of tissue health and diagnosis of cartilage degeneration and other injuries.

**COLLABORATORS:**

- Austin Health, Melbourne
- Brain Research Institute, Melbourne
- Royal Melbourne Hospital
- The AIBL study group
- Florey Institute of Neuroscience
- Queensland Institute of Medical Research
- McCusker Foundation
- Queensland Cerebral Palsy and Rehabilitation Research Centre
- University of Queensland
- Siemens Healthcare
- University of Western Australia

**PROJECT HIGHLIGHTS FOR 2015/16:**

- Development of a method to quantify structures from neonatal MRIs.
- Development of a method for improved regional measures of the cartilage from biochemical MRIs at 3T/7T.
- Development of a method to quantify Tau from PET tracers.
- Journal papers in top rated medical imaging and clinical journals.
- Prototype ChondralHealth software delivered to Siemens for internal evaluation.
- CapAIBL and CurAIBL neuroimaging software provided to Australian researchers on the NECTAR cloud.
- Successful grant funding, including NHMRC

**PROJECT AIMS FOR 2016/17:**

- Develop a Tau and cholinergic imaging biomarker using PET images.
- Initial development and validation of methods based on deep learning.
- Evaluation of ChondralHealth software in a multicentre study.
- A new project aimed at assessing Iron in ageing and Alzheimers disease.
- Develop approaches to quantify Iron and hippocampus subfields from advanced 3T and 7T MRI sequences.
- Develop approaches to quantify visceral fat from 3T MRI.

**PHD STUDENT PROFILE****Name: Anthony Paproki****University of Queensland**

**AUTOMATED IMAGE ANALYSIS OF HIGH-FIELD AND DYNAMIC MUSCULOSKELETAL MRI**

Abnormal knee biomechanics and injury to the menisci and posterior cruciate ligament (PCL) have been shown to increase the risk of developing knee osteoarthritis (OA). In his PhD, a set of image analysis algorithms were developed to allow the automatic quantitative analysis of the morphology and biochemistry of the knee joint. In addition, automated kinematic measurements are extracted from dynamic (in motion) MR images.

These measurements offer several avenues to study early pathophysiological changes associated with pre-osteoarthritic degeneration and assess the structural integrity of the menisci and ligaments post-surgery or investigate abnormal bone tracking or contact mechanisms for predicting subsequent risks of cartilage wear.

## CLINICAL IMAGING

**With the wide availability of scanning technology, radiological information has become an increasingly abundant resource that is used for a wider array of disease. However, even as demands on reporting physicians have risen, our ability to interpret the increasing amounts of data have not, so the available data remains relatively underexploited. Critical to addressing this gap is understanding the needs in individual clinical areas and the development of software to convert the data to information to present the relevant information.**

The clinical imaging team combines their knowledge of the clinical challenges that their collaborating physicians have, with a 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. This is used to assist in stratifying patients for treatment and understanding the reasons for treatment failure, which will also lead to better use of medical resources.

### NEURODEVELOPMENT OF THE PRETERM INFANT

The infant born very preterm (23-31 weeks gestation) is at high risk of an adverse neurodevelopmental outcome (10% cerebral palsy, 50% learning and behavioural difficulties at school age) which, if present, results in costs of billions of dollars annually in Australia. In the several months after very preterm birth, the brain is at its maximal capacity for neuroplasticity and repair.

This project aims to predict adverse neurodevelopment earlier and more accurately than currently possible in a cohort of 250 babies. This will be achieved using (i) advanced brain MRI to determine the structural wiring diagram of the brain ('brain connectome'), (ii) dense array EEG to establish the functional activity or electrical 'traffic' being carried on the main branches of the connectome and (iii) structured clinical neurodevelopmental assessments to provide a cutting edge view of the state of brain development. The significance of this research project is that it will represent a major advance towards better neurodevelopmental outcomes for preterm babies.

### RISK STRATIFICATION OF AORTIC ANEURYSMS

The repair of endovascular aneurysms is an increasingly common but complex surgical procedure. Extensive planning before surgery is required and it is important to assess how much vessels twist, because this increases the difficulty of the procedure. However surgeons typically assess tortuosity and calcification by eye, and accurate computational methods for this purpose are not readily available.

In collaboration with clinicians and researchers at the University of Adelaide, we are developing a computational approach to assess tortuosity and calcification.

#### **Assessing Liver Fibrosis from Texture Analysis**

Working with our partner, Resonance Health, we are seeking to examine potential methods to classify the severity of liver fibrosis from MR images. This problem is important, because liver fibrosis is difficult to detect at the early stages, when it can be resolved comparatively inexpensively. The only definitive way to assess fibrosis is by extracting a biopsy sample, which is too invasive to be used, unless disease is strongly suspected, hence the need for a non-invasive method. Imaging based biomarkers can complement blood-based biomarkers.

### TARGETING EXISTING THERAPIES WITH INNOVATIVE TECHNOLOGY PLATFORMS TO IMPROVE SURVIVAL IN BRAIN CANCER

In this project imaging biomarkers are being used to identify where and why the treatment of brain cancer fails at an earlier stage than has previously been possible. Being in the brain, these tumours cannot be completely removed during surgery and often regrow rapidly. For this reason, after surgery, both chemotherapy and radiotherapy are given to patients to deal with the remaining cancer cells, but the cancer usually returns with devastating consequences.

This research is important because brain cancer, although rare, can occur at any time of life including childhood and the ability of brain cancer to overcome therapy is poorly understood. A better understanding of brain cancer will be useful for other cancers as well.

### MR ALONE RADIATION THERAPY PLANNING FOR PROSTATE CANCER

In collaboration with the Calvary Mater Newcastle Hospital, and with funding support from the Prostate Cancer Foundation Australia and the NSW Cancer Council, CSIRO have developed the first atlas-based method to map accurate electron densities to MRI scans for dose calculations. The benefits of this approach will lead to more accurate treatment target localisation, reduced side effects, and costs savings. After two successful retrospective trials involving eighty men the first international multi-centre prospective trial for MRI-alone external beam radiation therapy for localised prostate cancer is scheduled for the second half of 2016.

### RADIOTHERAPY TREATMENT FOR PROSTATE CANCER - A CHANGE IN PRACTICE BASED ON DIRECT EVIDENCE FOR TARGETING AND TOXICITY EFFECTS USING REAL OUTCOMES DATA

Radiotherapy, if delivered accurately, can provide an effective treatment for locally advanced prostate cancer. Several factors stand in the way of optimal use of radiotherapy in this context, and this NHMRC funded project (\$594,000, 2015-2018, 1077788) aims to use an extensive, high-quality clinical trial dataset, in combination with innovative techniques developed by this project's investigators, to address those factors.

This study will allow; 1. quantification of the impact of observer definition of the prostate on treatment efficacy, by correlating long-term treatment failure with prostate segmentation uncertainties; 2. assessment of the impact of magnetic resonance (MR) imaging as a standard tool for identification of the prostate organ for informing radiotherapy treatment; 3. identification of anatomical regions that are being consistently under-dosed leading to treatment failure, by mapping regional radiotherapy dose distributions to treatment failures; and 4. identification of the anatomical origins of treatment-related toxicity, by mapping regional radiotherapy dose distributions to observed normal tissue toxicities.

### REDUCING THE GREATEST UNCERTAINTY IN RADIOTHERAPY

Radiotherapy is a well-established, cost-effective treatment which has 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 (\$536,000, 2016-2018, 1102198), in collaboration with the major Australian radiation oncology centres, involves the development of the first automated approach to contouring assessment using 4 large clinical trial datasets with the aim of changing practice for future studies and enabling consistent assessment in the clinic.

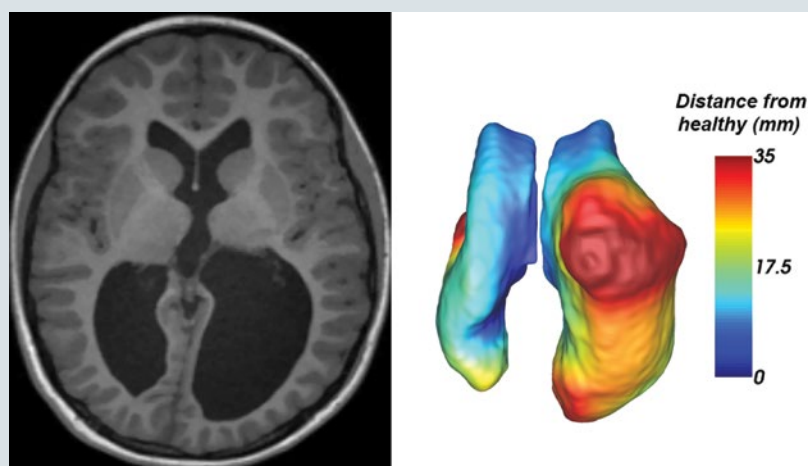


Figure 1. Structural MRI of patient with cerebral palsy displaying severely enlarged lateral ventricles. The extent of enlargement relative to healthy ventricles is displayed on the right.

## CLINICAL IMAGING *(continued)*

### COLLABORATORS:

- Departments of Radiology & Hepatology, Princess Alexandra Hospital
- Departments of Neurosurgery, Radiology, Radiation Oncology, and Nuclear Medicine, Royal Brisbane and Women's Hospital
- Department of Vascular Surgery, Royal Adelaide Hospital
- Queensland Cerebral Palsy and Rehabilitation Research Centre
- University of Queensland
- University of South Australia
- Genesis Healthcare
- Resonance Health
- Trans Tasman Radiation Oncology Group (TROG)
- Ingham Institute for Applied Medical Research
- Calvary Mater Newcastle Hospital
- Sir Charles Gairdner Hospital
- Liverpool and Macarthur Cancer Services
- Peter MacCallum Cancer Centres
- University of Newcastle
- University of New South Wales
- University of Western Australia
- University of Melbourne
- University of Sydney

### PROJECT HIGHLIGHTS FOR 2015/16:

- Successful completion of a project with commercial partner, Resonance Health, to assess liver fibrosis using texture analysis, which has to lead to larger, ongoing follow-on project. Both projects were co-funded by the Department of Industry and Science.
- Development of a method for separating multiple PET tracers that generalises to any type of tracer and any biology or disease.
- Development of improved software to extract iliac arteries from CT images and describe their shape while quantifying the extent of calcification.
- Acceptance of 5 papers on the various aspects of the analysis of MR images of children with Cerebral Palsy.
- Results published demonstrating the feasibility of MRI-based prostate cancer radiation therapy (Dowling et al. 2016, IJROBP, 93(5))
- Successful grant funding, including NHMRC, two CSIRO Office of Science Excellence Post Doctoral Fellowship grants.
- Journal papers in top rated medical physics and radiation oncology journals.

### PROJECT AIMS FOR 2016/17:

- Develop approaches using imaging to assist surgeons in planning partial hepatectomies.
- Complete development of method to assess interstitial fluid pressure within tumours non-invasively.
- Start development of motion correction methods to improve the analysis of dynamic image data.
- Development and validation of methods for automatic radiation oncology clinical trial quality assurance.
- First international multi-centre prospective trial for MRI-alone external beam radiation therapy for localised prostate cancer.
- A new project aimed at MRI based non-invasive lung structure assessment for children with cystic fibrosis.

### PHD STUDENT PROFILE

**Name: Alex Pagnozzi**

**University of Queensland**

**APA Scholarship and PhD Top-up Scholarship**

**AUTOMATED INJURY SEGMENTATION TO ASSIST IN THE TREATMENT OF CHILDREN WITH CEREBRAL PALSY**

Cerebral palsy is the most common physical disability of children worldwide. Accurate diagnosis and prognosis is difficult due to the variability in type and in extent of injury that occurs, which leads to inconsistency in the clinical outcomes children with CP. The routine use of

Magnetic Resonance images could increase consistency, but currently this is a manual and labour intensive process, that is not widely performed.

In this PhD, a series of automated image quantification techniques was developed for automatically analysing the MRI data obtained from children with Cerebral Palsy. These techniques identify and quantify the severity of the three main types of injury observed in children with CP; including ventricular enlargement, cortical malformations and white and grey matter injury. These methods can repeatedly and automatically provide a delineation of lesions,

and through the statistical models, estimate patient outcome, which can help guide treatment and therapy decisions.

This has the potential to benefit the wider scientific community, where the translation of structural MR-derived biomarkers to functional outcomes can help the understand of the aetiology of CP and the structure-function relationships of the brain, as well as children with CP, where the prediction of functional outcomes can help guide effective intervention strategies and can lead to greater improvements in function.

## TRANSFORMATIONAL BIOINFORMATICS

The transformational bioinformatics team develops and applies advanced computational tools to health/life sciences data using cloud, high-performance compute or Hadoop/Spark technology. We develop algorithms that can jointly harnesses information from diverse sources like genomic profiles, personal sensing devices, and electronic health records from population-scale cohorts to build "smart analytics" systems that are predictive of health outcomes

### CLOUD-BASED GENOME ANALYSIS TOOLS

The cloud-based genome analysis project aims to provide tools for combining medical data from individuals with the information from large scale genomic studies to analyse individual risk and health outcome. We developed VariantSpark, a machine learning analysis framework for genomic data, utilizing the BigData Spark engine to enable real-time analysis.

#### Outcome

- Publication in BMC Genomics listed in the top 5% of all research outputs scored by Altmetric.
- Collaboration with Berkeley and the Broad Institute on Spark-based genome analysis
- VariantSpark is available at <http://bioinformatics.csiro.au/variantspark>

### NHMRC DEMENTIA TEAM GRANT: MOTOR NEURONE DISEASE AND DEMENTIA

This Dementia Team Grant was one of only 6 funded applications worth \$6.5M, let by Ian Blair (MQ). The project aims to uncover the molecular mechanisms of Amyotrophic Lateral Sclerosis (ALS), the disease Stephen Hawking suffers from. 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 5 year project. This effort contributes towards the international Project MinE, which will analyse the genomes of 15,000 ALS patients and 7,500 healthy controls in a bid to understand the genetic origins of these devastating neurodegenerative diseases.

#### Outcome

- CSIRO researchers have identified more than 60,000 potentially disease contributing mutations of familial ALS in a twin study conducted by Prof. Ian Blair and Dr. Kelly Williams at Macquarie University.
- By linking information from medical literature and large scale genomics projects, CSIRO helps to prioritize variants for further testing.
- VariantSpark was applied to the exome sequences of 137 allegedly unrelated ALS patients to uncover hidden familial relationships thereby increasing the statistical power to classify disease variants.

### GENOTYPING HLA IN-SILICO FOR MELBOURNE GENOMICS HEALTH ALLIANCE

The abundance of genomic sequencing data enables pathology tests to be performed in-silico rather than requiring the expensive and time-consuming process of obtaining a dedicated new sample and performing a laboratory test. In collaboration with the MGHA, we investigated if current computational programs are capable of typing the HLA genotype of an individual from generic whole exome, whole genome or transcription data with comparable accuracy than the currently accepted gold standard laboratory method, SBT.

#### Outcome

- Publication in Briefings in Bioinformatics (IF=8.4)
- Recommendation to not use in-silico HLA typing for clinical practice just yet

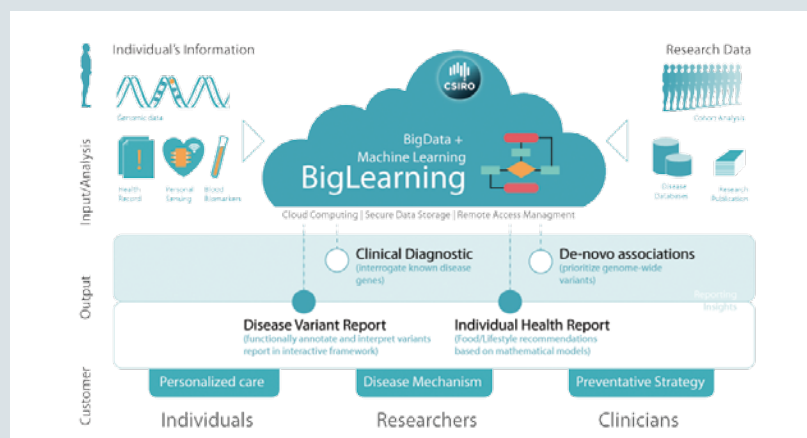


Figure 1. Cloud-based smart analytics framework

## TRANSFORMATIONAL BIOINFORMATICS *(continued)*

### COLLABORATORS:

- Macquarie University
- University of Newcastle
- Australian National University
- Australian Genomics Health Alliance
- ASPREE Melbourne University
- NCI
- Melbourne Genomics Health Alliance
- Graven Institute for Medical research
- The Broad Institute, USA
- UC Berkeley, USA
- The Jackson Laboratory for Genomic Medicine, USA

### PROJECT HIGHLIGHTS FOR 2015/16:

- The team's work has led to 5 first/senior author and 5 co-author paper with three in high impact journals (Genome Research IF=15, Nature Protocol IF=13.47 and Blood IF=10).
- We had 6 first/senior conference presentations and were invited to the international COMBIO conference and bioinformatics winter school.
- The team helped secure \$25M in competitive funding with more than \$2M in the funding pipeline.

### PROJECT AIMS FOR 2016/17:

- Develop cloud-based analysis tool for Genome Engineering applications (a market estimated to reach \$US40B by 2020).
- Help set up Spark-based genome analysis pipelines at NCI catering for Australian Genomics Health Alliance
- Establish VariantSpark internationally as the tertiary analysis for large cohort analysis

### STUDENT PROFILE

**Name: Florian Heyl**

**Masters Student through the German Bioinformatics Exchange Program**

TOPIC: HOW DOES THE METHYLATION PROFILE INFLUENCE GENE REGULATION THROUGH ALTERNATIVE SPLICING

Splicing transcripts are an essential and highly precise regulated process, which elevates the complexity in the genome but also increases the susceptibility to malfunction, such as cancer. While it has been well documented how sequence motifs and individual variations influence splicing events, less focus has been given to the direct role of DNA methylation despite evidence of its involvement.

Florian investigates how the methylation profile of the genomic environment surrounding the exon affects splicing by using matching whole genome bisulphite and whole transcriptome sequencing data. We first identified exons that are spliced out of actively expressed genes using a probabilistic model developed by Xiong et al. (Science, 2015). Florian has observed that on average spliced out exons have a 2-fold increase in methylation rate for both the up- and downstream intron compared to the retained exons (150bp region surrounding the exon, p-value <  $1.7 \times 10^{-197}$ ), while the methylation of the exon itself remains stable (p-value=0.456).

Following this observation, he used a deep-learning approach to build a model on these interacting features over thousands of base pairs to predict whether an individual exon is excluded or retained. He achieved a very high prediction accuracy, which demonstrates the direct impact of local methylation profile on splicing events.

## BIOSTATISTICS

The AEHRC 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 work with internal and external collaborators to investigate destructive phenotypes in diseases such as Alzheimer's disease, inflammatory bowel disease and cancer. Fostering the development of young and talented statisticians, the team works with two PhD students developing new methods to analyse disease phenotype. Further to this each year the team engages top ranking undergraduate students in summer projects that both challenge their skills and work towards novel research outcomes.

### CRC FOR MENTAL HEALTH

The team are key members of the CRC for Mental Health. The core mandate for the CRC is undertaking research to identify and validate biomarkers for the early detection and treatment of neurodegenerative disorders and psychoses. By bringing together industry, end users and health care providers, the CRC aims to develop and commercialise our research findings in order to deliver changes to treatment in medical and health care practices. This year the biostatistics team's research in biomarkers for the early detection of Alzheimer's disease led to six publications and 13 conference presentations. Key research from the team led to many high ranking publications, including a paper describing altered innate phagocytosis function in Alzheimer's disease, and another describing suspected non-Alzheimer's disease pathophysiology.

### CRC IN COGNITION AND ITS DISORDERS

Members of the team provide 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 Alzheimer's disease, 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 Parkinson's disease, 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 terrible disease. This research has led to six journal publications in high-ranking journals.

### INFLAMMATORY BOWEL DISEASE

The team are key members of the Australian inflammatory bowel disease consortium, which has a major research focus in Crohn's disease and Ulcerative Colitis. Providing research support to key research in the treatment of Crohn's disease, the team is currently working on the world's first direct comparison of human and mouse monoclonal antibodies with or without immunosuppressive treatment. A manuscript is currently under review that showcases these results. Further to this, research has also been conducted on biomarkers associated with acute severe ulcerative colitis, with a new diagnostic index being identified. The Team also collaborates with the International inflammatory bowel disease genetics consortium, which has both SNP and clinical data from over 70,000 individuals, and as part of a worldwide effort and finding biomarkers related to both the presence of disease, and disease progression.

### Cancer genetics

Developing new statistical methods and novel statistical pathways to analyse cancer genetics data, the team collaborates with Biostatistics Department at the MD Anderson Cancer Centre in Houston Texas. Using the world's largest resource of cancer genetic data from The Cancer Genome Atlas (TCGA), the team works with statisticians to create new methodologies that will unravel the complex etiology of cancer. New methods have been able to discover new case related genes and find sets of genes with high accuracy to predict outcome.

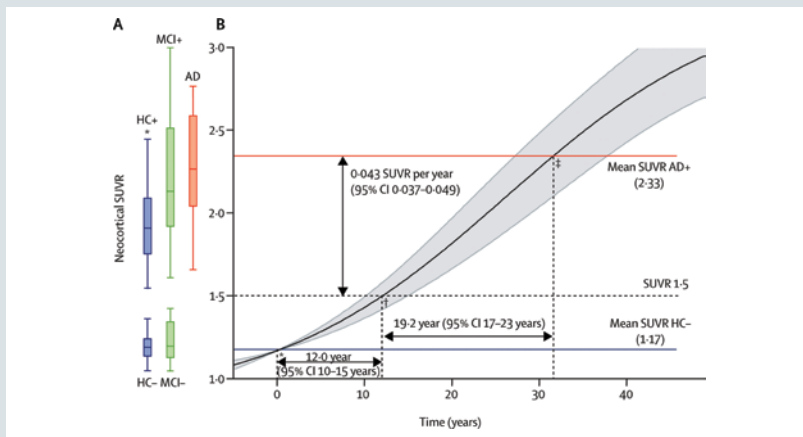


Figure 1. Alzheimer's disease progression model

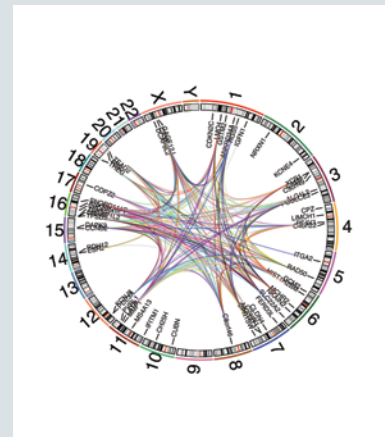


Figure 2. Cancer gene associations across the genome

### COLLABORATORS:

- CRC for Mental Health
- 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

### PROJECT HIGHLIGHTS FOR 2015/16:

- Real beach to bedside research with biomarker studies leading to changes in clinical practice.
- 13 published and 3 accepted journal article - including first author papers in Lancet Neurology (IF22) and Neurology (IF8)
- 13 conference presentations

### PROJECT AIMS FOR 2016/17:

- 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

### PHD STUDENT PROFILE

**Name: Charley Budgeon**

**PhD Student with the Centre for Applied Statistics at the University of Western Australia.**

**TOPIC: PERSONALISED SURVIVAL ANALYSIS IN ALZHEIMER'S DISEASE**

Charley was successful in obtaining a CSIRO top-up scholarship for her project and is co-supervised by Sam Turnham in our Floreat office in Perth WA. Charley presented her work on combining multiple short-term follow-up data on individuals on the Alzheimer's disease course to map the full disease trajectory at AAIC 2015 (the "Big" Alzheimer's conference) in Washington.

This work is particularly important as AD represents a major economic and social burden which requires a cure to avoid crippling health services, the best chance for a cure or delay to onset is believed to exist in therapeutics administered at the earliest stages of disease. However, without an understanding of the full disease course determining the appropriate window for treatment is challenging. Charley's work has identified methods to "stitch" such short-term follow-up data, from many individuals, together to try to underpin the full disease trajectory.



# HEALTH SERVICES

## 2015/16 SCIENCE AND IMPACT HIGHLIGHTS

- The AEHRC's first spin out company, Cardihab, was incorporated and incubated within the AEHRC to commercialise the Mobile Phone Based Delivery of Cardiac Rehabilitation program.
- CSIRO completed the first National Telehealth Trial, funded by the Commonwealth Government Telehealth Pilot Program and the CSIRO with additional in-kind support provided by clinical and industry partners. The trial involved trialling telehealth systems with 287 patients over a 12 month period. It showed savings of 24% over the year to the healthcare system made through reduction in the number and cost of GP visits, specialist visits and procedures carried out.
- The Health Services group has developed other mobile health delivery programs which are due to undertake clinical trial over the next 12-18 months with our clinical partners. These include delivery models for patients with chronic diseases, such as diabetes and COPD, for patients who have had surgery, such as a Total Knee Replacement and for patients who need their wounds managed remotely.
- The AEHRC have started a mobile health trial with the Institute for Urban Indigenous Health (IUIH), producing a digital version of the IUIH Work It Out program.



**MOHAN KARUNANITHI**  
Health Services  
Group Leader

Mohanraj Karunanithi has a doctorate in Biomedical Engineering, University of New South Wales. He has over 10 years of experience in cardiac research and 5 years of medical industries' experience. At AEHRC, he manages and coordinates research in ICT application in healthcare management and delivery of chronic diseases and aged care.



**SIMON MCBRIDE**  
Mobile Health Solutions  
Team Leader

Smartphones, apps, wearable devices and other types of mobile computing are the most rapidly adopted forms of technology in human history. Widespread adoption in combination with the capabilities of these devices provides a significant opportunity for re-imaging the delivery of health care. Our Mobile Health Systems team has been recognised by prestigious international journals as a world leader in providing scientific evidence supporting m-health. We aim to make the delivery of chronic disease management and aged care services accessible to all communities. The team works with our clinical partners to develop and trial technology enabled services to deliver healthcare to people in their homes and communities.



**JILL FREYNE**  
Engagement and  
Effectiveness  
Team Leader

Our Engagement and Effectiveness team draws on expertise across Human Computer Interaction, Personalisation & Recommendations, 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 technologies 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 the e-Health program and into several other CSIRO Business Units.



**YOGI KANAGASINGAM**  
Australian Tele-health  
Research and  
Development  
Group Director

The Australian Tele-health Research and Development Group is our partnership with the Western Australian Department of Health and our Western Australia node of the Australian e-Health Research Centre (AEHRC).

The team based in Perth conducts research projects investigating the use of telemedicine to provide healthcare to rural and remote Australia and to identify new screening methods for diseases that are possible to implement using tele-medicine. The current focus is the development of novel telemedicine technologies in the form of non-invasive ocular imaging techniques for chronic diseases such as Diabetes and for neuro-degenerative diseases such as Alzheimer's disease and stroke.

# PROJECTS

## MOBILE HEALTH SOLUTIONS

**Smartphones, apps, wearable devices and other types of mobile computing are the most rapidly adopted forms of technology in human history. Widespread adoption, with the combined capabilities of these devices, provides a significant opportunity for re-imaging the delivery of health care.**

Our Mobile Health Systems team has been recognised by prestigious international journals as a world leader in providing scientific evidence supporting m-health. We aim to make the delivery of chronic disease management and aged care services accessible to all communities. The team works with key clinical partners to develop and trial technology enabled services to translate and deliver healthcare to people from hospital to in their homes and communities.

### MOBILE HEALTH CARDIAC REHABILITATION AT WEST MORETON HHS

This implementation project was supported by the West Moreton Hospital and Health Service (WMHHS) Health Innovation Fund. It evaluated the effectiveness of integrating a validated home-based care model of cardiac rehabilitation (MoTER-CR) into existing clinical practice at WMHHS. MoTER-CR, which uses a smartphone and the Internet to deliver cardiac rehabilitation to patients at home, was offered from May 2015 to June 2016 as an alternative for patients who were unable/unwilling to attend the WMHHS centre-based cardiac rehabilitation program. The evaluation confirmed the outcomes of previous results from a CSIRO/Queensland Health managed clinical trial to determine if the positive results from the trial were transferrable to a "real world" setting.

During the implementation period, 27 patients (17 male; 10 female; Age  $53.2 \pm 9.7$ ) commenced on the MoTER-CR program. This was 30% of patients suitable for cardiac rehabilitation and most of these patients would not have enrolled in a rehab program if the home-based option was not available. Adherence rate (completing at least 4-6 weeks of the MoTER-CR program) was 88% which is comparable to the remarkably high adherence rate of 94% obtained in the clinical trial. Clinical outcomes were also similar to the controlled trial results. Patients showed significant improvement in functional capacity with a 54.3m (ave) increase in 6 Minute Walk Test. The majority of the participants enrolled in the MoTER program were either overweight or obese with BMI more than 25 kg/m<sup>2</sup> and there was a slight but significant decrease in weight at completion of the 6-week program (-1.5kg) and a slight decrease in waist circumference.

There were no significant changes in blood pressure in male or females and both were within normal ranges at baseline and follow-up. All the patients (100%) found the MoTER-CR App easy to use and useful to them with 86% indicating that the app motivated them in reaching their goals.

Comments from patients include:

- "It was good to keep in touch with someone. Someone to talk to if any issues. It was good to talk about progress"
- "I found it great to hear from the clinician every week. The support was very encouraging."
- "I felt that I had a guardian angel"

The project generated positive media coverage with Channel Nine Brisbane featuring a 2:15min story on Sunday 20 December 2015. The outcomes of the implementation study was also selected from 11,000 scientific abstracts to be presented in one of the main sessions "Advances in Science" at the prestigious European Society of Cardiology Congress 2016.



Figure 1. Channel Nine feature about the trial with West Moreton HHS

### MOBILE HEALTH FOR CHRONIC DISEASES MANAGEMENT - METRO SOUTH HHS

A number of multi-site projects for chronic disease services within Metro South Hospital and Health Service (MSHHS) have been approved and are at various stages of planning and implementation at MSHHS:

The first of these projects is the implementation and evaluation of the MoTER-CR program to be offered as an alternative program to the centre-based cardiac rehabilitation program to increase the usage of rehab across MSHHS. Additionally, the MoTER-CR app will be used to support patients attending the centre-based CR programs and patients will also be able to complete a 'hybrid' program with initial centre-based followed by home-based CR. Such offerings could potentially result in improved patient experience and satisfaction including predicted reduction in service delivery cost and readmissions. Moreover, innovation funding has been secured which will provide an opportunity to increase service capacity of chronic disease management services at MSHHS within existing resources by extending the platform to other chronic conditions, gestational diabetes mellitus and kidney disease.

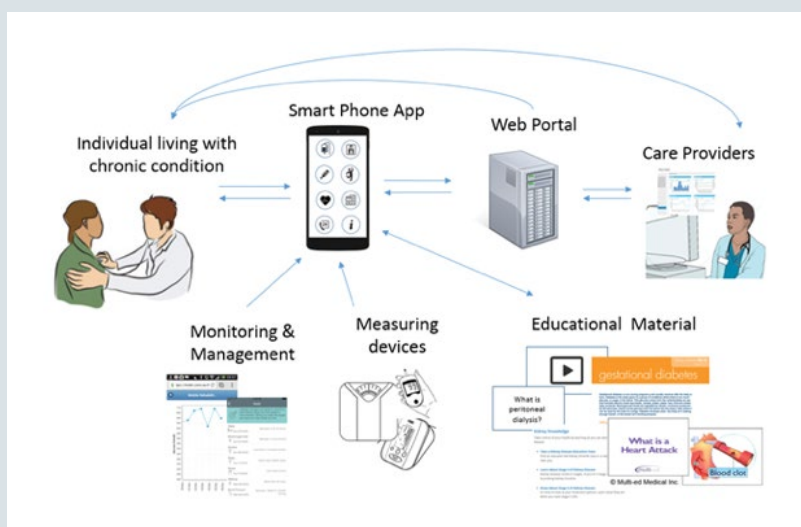


Figure 2. Smartphone and Internet platform for chronic disease management at Metro South HHS

### MOBILE HEALTH FOR NEWLY DIAGNOSED DIABETES PATIENTS - METRO SOUTH HHS

In 2015, the CSIRO Mobile Health team conducted a feasibility study to develop and evaluate a mobile health system for delivery of the insulin stabilization service (ISS) at the Princess Alexandra Hospital. The increasing prevalence of diabetes has led to a huge burden to the insulin stabilization services nationally. Additionally, the traditional data collection via paper based diary is time consuming for clinicians, and many diabetic patients are unable to adhere to the monitoring requirements for the clinical interventions.

To address these issues, we worked with endocrinologists and nurses at PAH to develop a mobile health based program with the following core components:

- Integration of the latest Bluetooth enabled glucose meter (Accu-Chek Aviva Connect) and mobile health applications for clinical interventions
- Self-management tools for diabetic patients to record blood glucose levels, insulin dosages, and assessments by self-observation
- Scheduling tools for collaborative care and clinical follow-ups
- Mobile messaging system to simplify certain clinical interventions
- Structured reporting and discharging forms

## MOBILE HEALTH SOLUTIONS *(continued)*

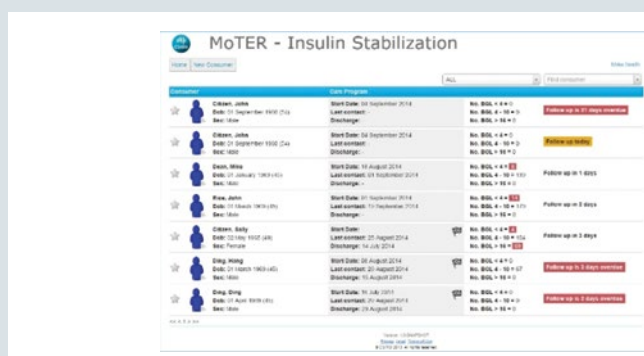


Figure 3. Clinicians' portal to review patients' data



Figure 4. Smartphone app to monitor health data and ISS action plan

Through the trial, we demonstrated that diabetic patients in the trial ( $n=10$ ) were able to use the wireless glucose meter to easily record the blood glucose levels, and the mobile health application was generally accepted by the patients.

To further evaluate the mobile health delivery of ISS, we will be conducting a randomized controlled trial in 2016/17. In the trial, we will recruit 40 diabetic patients, and randomize the patients into two groups, intervention group ( $n=20$ ) and usual care group ( $n=20$ ). Finally we will compare the outcomes between the two groups to examine whether the mobile health delivery of ISS would improve the adherence to ISS in diabetic patients, as well as clinical outcomes such as HbA1c, variation of blood glucose levels, and reduced risks of episodic diabetic events. We will also evaluate the associated economic benefits to extend the mobile health program for future studies.

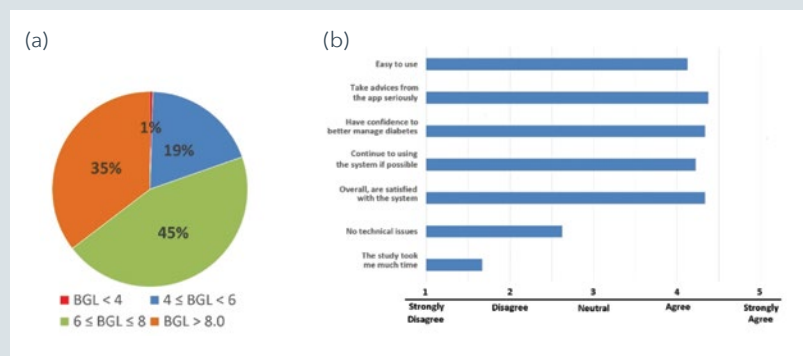


Figure 5. Distribution of before-meal BGL entries in mmol/L (a), and average scores of the acceptance questionnaire (b).

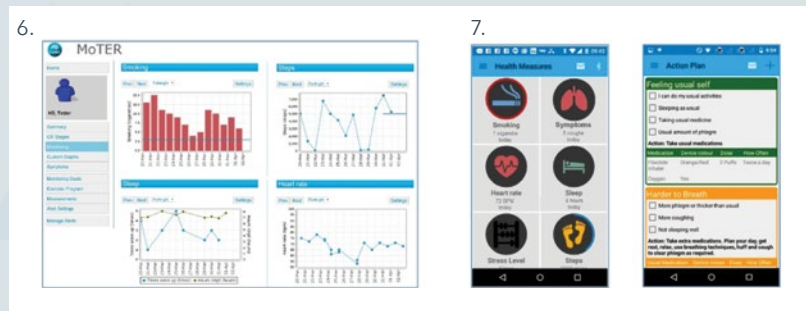
### MOBILE HEALTH FOR MANAGING COPD PATIENTS - METRO NORTH HHS

In 2015, the CSIRO Mobile Health team initiated a collaborative research project to improve the management of Chronic Obstructive Pulmonary Disease (COPD).

COPD is the third leading cause of death worldwide, and leads to direct health care costs of estimated 8.8 billion dollars annually in Australia. Many patients with COPD are unable to manage their health conditions in compliance with the evidence based clinical guidelines and, hence, have high risks of COPD exacerbations and associated hospital readmissions.

To address these issues, this project uses an innovative mobile health system to deliver an enhanced clinical care program focusing on the following aspects:

- Structured automated delivery of the educational program by the Lung Foundation Australia (LFA)
- Monitoring of COPD symptoms for timely interventions
- Promotion of physical activity in compliance with COPD guidelines
- Electronic COPD action plan
- Automated smoking cessation program
- Inhaler technique and monitoring of inhaler medications.



To evaluate the mobile health enhanced COPD program, a randomized controlled trial will be conducted in 2016/2017.

Figure 6. Clinicians' portal to review patients' data

Figure 7. Smartphone app to monitor health data and COPD action plan

## MOBILE HEALTH FOR STEM CELL TRANSPLANT CANCER PATIENTS - LEUKAEMIA FOUNDATION OF AUSTRALIA

Blood cancer is the third biggest cause of cancer death across Australia, claiming more lives each year than breast cancer or skin cancer. Intervention treatment provided to blood cancer patients often include high doses of chemotherapy and radiation. Managing and monitoring the symptoms associated with treatment is crucial for clinical outcomes and Quality of Life of the patient(s). The Leukaemia Foundation (LF) provide services to inform and actively engage patients in their recovery process, however this comes at high cost. In collaboration with RBWH and LF, AEHRC is developing a mobile based platform to improve symptom management and the delivery of information for blood cancer patients.

The platform proposed utilises smartphone technology for both recording of symptoms and content delivery. Entries to the application are linked to a web platform for carers to assess and provide individualised feedback. Working with LF is paramount to integrating the relevant content for the application to be generated, to properly inform and educate patients about their symptoms and self-management.

We believe the proposed smartphone application has the potential to improve the appropriate and relevant information delivery and quality of life for patients with blood cancer. Moreover, the uptake and delivery the mobile application could potentially reduce costs to both patients and healthcare services. To validate the new care delivery model for the management of blood cancer patients, the mobile health platform will undergo a clinical trial in the near future.

### Collaborators:

- The Prince Charles Hospital
- The University of Queensland
- The Lung Foundation Australia
- Metro North Hospital and Health Service, Queensland Health.
- The University of Queensland
- The Princess Alexandra Hospital
- Centre for Online Health
- Metro South Hospital and Health Service, Queensland Health.

## REMOTE MONITORING OF PEOPLE WITH PARKINSON'S DISEASE

Parkinson's disease is a leading neurological disease that effect people from all walks of life. It typically presents with a high variance in symptomatology and requires a holistic approach to treatment and management. In order to understand conditions and the efficacy of medication treatment and intervention, a remote monitoring study has been ongoing with a collaboration with AEHRC and the University of Queensland. Core to this study is technology created at AEHRC for the sensing of a variety of data domains including movement, speech, and well-being that is send back to a portal where researchers and clinicians can access this data.

People with neurological conditions such as Parkinson's disease can have trouble finding the right words and may lose track of their message mid-sentence. Capturing naturalistic conversation to understand this phenomenon has been hitherto arduous due to a variety of piracy, ethical and technology limitations; however, this project has developed a particular tool that overcomes these obstacles in the form of a smartphone application that is a artificial intelligent conversation agent, or chat-bot called HARLIE.

HARLIE engages the user on small-talk mean while capturing the users voice and language abilities. Harlie has since evolved to become a standalone project that has been tested with the co-operation of numerous community groups where a variety of people of different cultural backgrounds, medical conditions and familiarity of technology were asked to have a chat and give us their feedback.

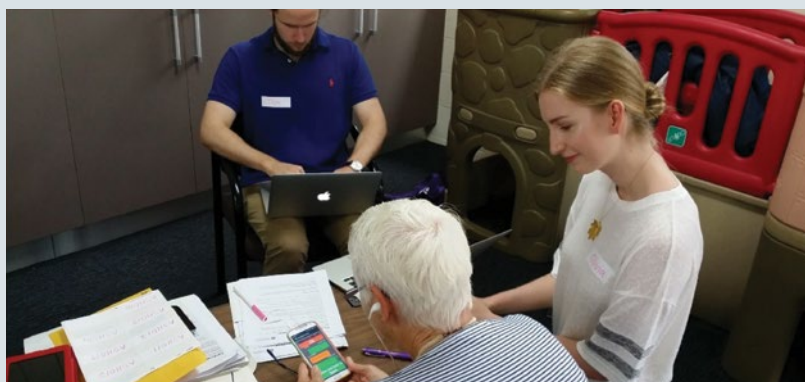


Figure 8. A participant speaking to HARLIE about spending more time with her family.

## MOBILE HEALTH SOLUTIONS *(continued)*

### HIGHLIGHTS FOR 2015/16:

- Implementation of mobile health delivery of cardiac rehabilitation in real life practice in West Moreton HHS confirmed improved uptake and completion of cardiac rehabilitation services – presented at leading international cardiac conference in European Cardiology Congress 2016.
- Development of mobile health solutions for delivery of COPD and insulin stabilisation of Type 2 Diabetes and pilot study was commenced.
- Harlie, the interactive speech mobile App was workshopped with a group of people with Parkinson's disease. HARLIE innovation received wide media release, including radio interviews, television and "The Conversation" articles.

### AIMS FOR 2016/17:

- To extend and test AEHRC mobile health platform for delivery of other chronic diseases, such as diabetes and respiratory diseases.
- To conduct clinical trials for mobile health delivery care models chronic disease management (Diabetes, COPD) and post-surgical Total Knee Replacement management.
- To conduct trials of mobile health delivery for cardiovascular screening and management of indigenous population
- Extend mobile health delivery to Chronic and Back pain management
- Extend HARLIE for other neurodegenerative conditions and elderly people

### PHD STUDENT PROFILE

**Name:** Nazli Ghafouryan

**TOPIC:** AEHRC PHD SCHOLARSHIP

The aim of this research is to develop and validate a mobile based virtual clinic based via customising a recently validated mobile health platform (MoTER) for the clinical management of patients with Acute Coronary Syndromes (ACS). This research study will consist of Phase1 (pre-study survey and pilot trial) and Phase 2 (randomised controlled trial). The pre-study survey of structured interviews with patients and a focus group (N=10) with healthcare professionals. will be used to define the requirements for customising the MoTER platform for ACS.

The pilot trial will test the MoTER App and web-portal for ACS management in 54 patients over 12 weeks. The MoTER platform will be used for providing education and personalised feedback, monitoring physiological data as well as recording patients' self-observations on their health related behaviour and virtual consultation via audio or video. The second phase trial will evaluate the virtual clinic effectiveness in a Randomised Controlled Trial (RCT) and assessing participants' clinical outcomes, quality of life and psychosocial wellbeing at baseline, 8 weeks and 6 and 12 months.

The project is currently of engaging patient group and clinicians for a pre-study survey for the customisation and development of MoTER platform to a Mobile Virtual Clinic for Acute Coronary Syndrome.

## AGED CARE/SMARTER SAFER HOMES

Australia's ageing population is steadily increasing. The proportion of the population aged 65 years and over will increase from 14.7% in 2014 to 22% in 2050. The health and wellbeing challenges facing the elderly, especially those living alone, can be significant and overwhelming, including a decrease in strength, endurance and flexibility; decline in organ function; reduction in bone mass; slowed reflexes and impairment of the senses, particularly vision and hearing. Health care expenditure increases with age, doubling between 45 and 65, and doubling again between 65 and 85. With such a large percentage of our ageing population facing injury, disabling or chronic disease, and regular medical care, health expenditure is rising faster than economic growth.



Figure 1: SSH - In-home monitoring and data analytics from ambient wireless sensors

### SMARTER SAFER HOMES (SSH)

The SSH project is led by CSIRO's Australian eHealth Research Centre with multidisciplinary collaboration including universities, aged care service providers and local clinicians. The CSIRO research team has developed an innovative in-home monitoring and data analytics platform, the SSH platform, that seeks to support and extend independence and improve quality of life for aged residents through the use of cutting edge pervasive communication and wireless sensor and monitoring technology.

The potential benefits of these technologies are multiplied where distance separates families and adds substantial costs to delivery of health and other services.

The SSH platform has been piloted in three states in Australia, in an independent living setting, a nursing care service, and with home care providers, respectively. The SSH platform was deployed to homes connected to either cable, broadband or mobile network.

These pilot studies helped the design and development of the SSH as a technology platform; the feasibility test of the SSH platform to deliver remote nursing services to elderly people living at home; the viability exploration of the SSH platform for home care providers to enhance their services for aged care residents and people with a disability.

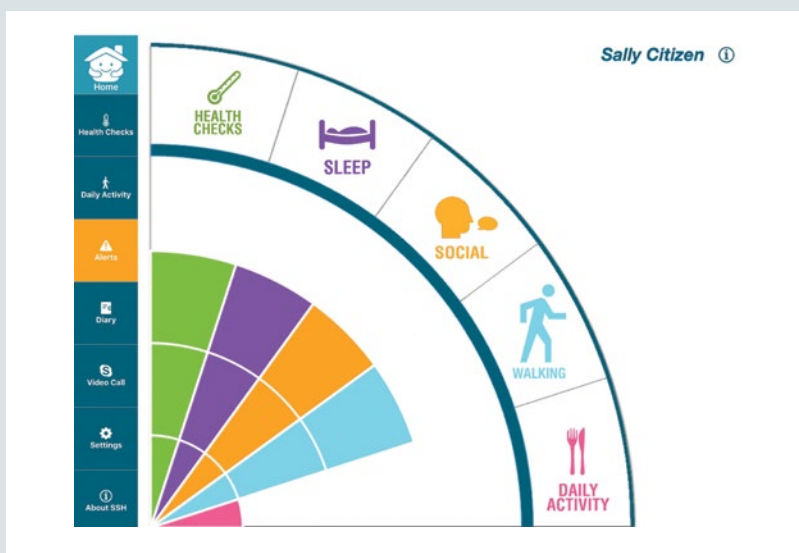


Figure 2: SSH iPad application allows residents to view data derived from the sensors and medical devices."

## AGED CARE/SMARTER SAFER HOMES *(continued)*



Figure 3: SSH clinical trials location, period and number of homes

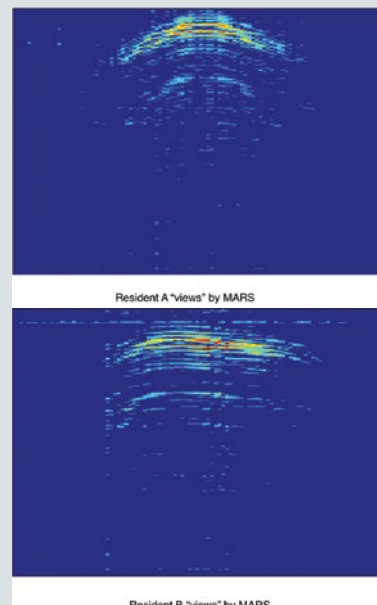


Figure 4: MARS recognises different residents in a smart home through its novel ambient radar sensor.

### SSH FOR MULTI-RESIDENTIAL ACTIVITY RECOGNITION SYSTEM (MARS)

The MARS project aims at designing and developing a novel human activity recognition system to identify and calculate activity of daily livings of individuals within a multi-residential environment. Compared to existing human indoor identification system, our tagless, ambient, non-intrusive (no video camera) system can be easily deployed in a Smart home to recognise individual activities with high accuracy. This system extends the current CSIRO Smarter Safer Homes platform to support effective and accurate health monitoring and assistance to individuals living in a home environment with multiple inhabitants.

### PROJECT 4 - ROBOTS FOR AGEING IN PLACE

In this project, we aim at developing an in-home aged care robot that can communicate data from smart home sensors as easy to understand information to assist elderly residents in their self management; understand/monitor mental health status through analysing the audio conversations with residents; provide future information to justify reminders and alerts in a smart home.

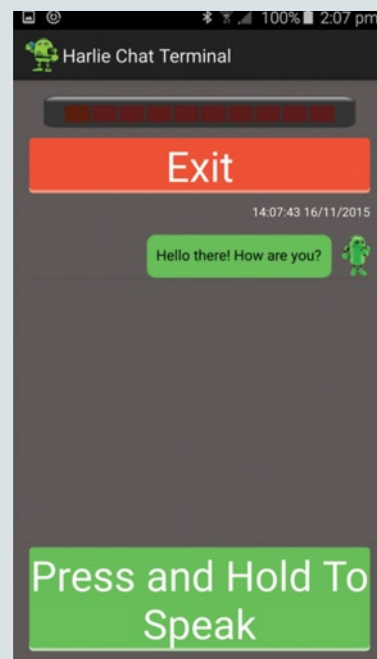
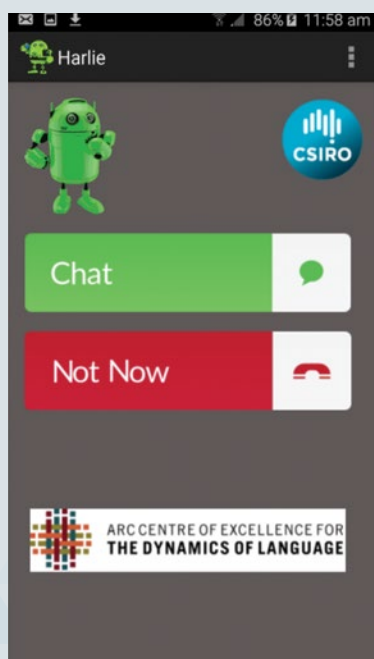


Figure 5: The robot's chat interface

**COLLABORATORS:**

- Data 61/Energy Flagship, CSIRO
- Autumn Lodge Aged Care
- RDNS Home Care
- Bromilow Home Support
- integratedLiving Australia
- QIMR Berghofer Medical Research Institute
- ORCATECH of Oregon Health & Science University, USA
- Community Resourcing Worldwide, Australia

**PROJECT HIGHLIGHTS FOR 2015/16:**

- Started a new Smart Home trial with 10 homes in Newcastle, NSW
- A patent to determine objective and personalised measure of Activity of Daily Living in Smart Home was filed
- The Smarter Safer Home white paper was published

**PROJECT AIMS FOR 2016/17:**

- Develop and evaluate Multi-Residential Activity Recognition System (MARS) in multi-occupancy home environment
- Develop aged-care assistive robots that can support in-home ageing of people with early onset of dementia
- Determine the cost and benefit of SSH platform technology to Australian aged care industry

**POSTDOC PROFILE****Name: Dr. Ghassem Mokhatari****TOPIC: NON-WEARABLE SENSOR TO DETECT FALLS IN SMART HOME**

This work proposed the use of ultra-wide band (UWB) radar technology to detect fall in smart assistive home environment. The UWB sensor was mounted over the room ceiling to detect fall in its detection zones. Four types of inertial activities were detected and distinguished based on their different patterns, such as normal/fast walk, laying and fall.

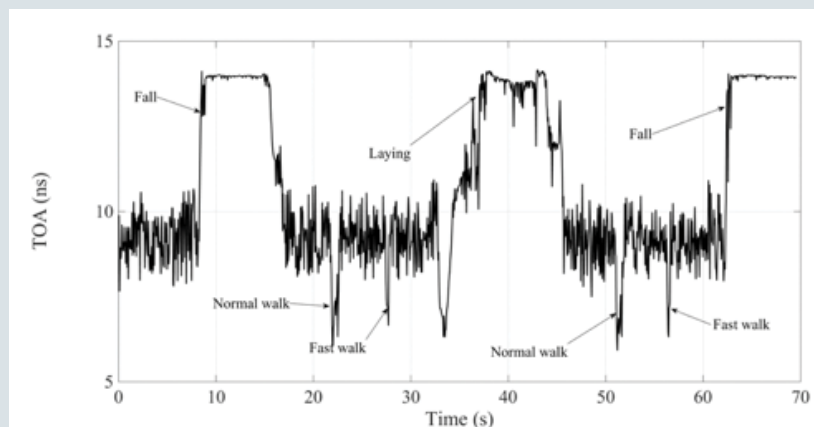


Figure 6: Various patterns detected by UWB sensors to identify fall

## ENGAGEMENT AND EFFECTIVENESS

The engagement and effectiveness team draws on expertise across Human Computer Interaction, Personalisation & Recommendations, 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 technologies 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 the e-Health program and into several other CSIRO devisions. In 2015/2016 the team engaged primarily with industry partners to deliver excellence in science.

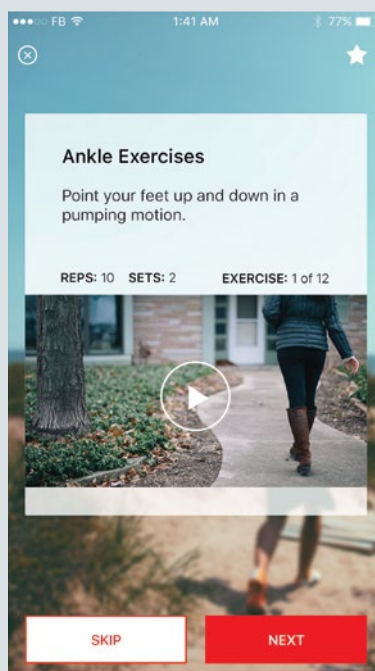


Figure 1. Activate TKR app: exercise video screen. Exercise programs are configured by physiotherapists from a library of videos typically used for TKR rehabilitation.

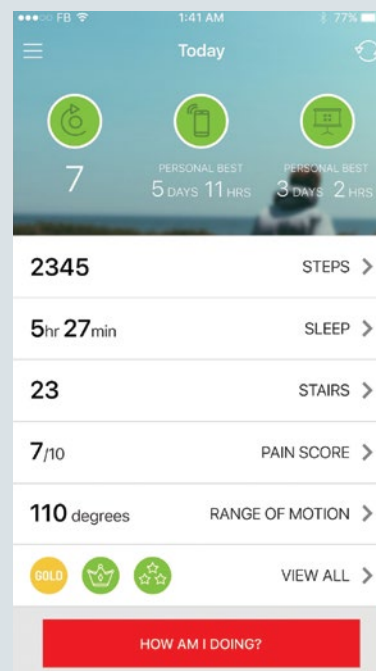


Figure 2. Activate TKR app: progress data screen. Shows data from the activity tracker (daily step, stairs, and sleep) and self-reports (pain and knee ROM).

### ACTIVATE TOTAL KNEE REPLACEMENT (TKR)

Total knee replacement (TKR) surgeries have increased in recent years. Exercise programs and other interventions following surgery can facilitate the recovery process. Patients, however, have a substantial burden of self-management and limited communication with their care team, thus often fail to implement effective rehabilitation plans.

The Australian eHealth Research Centre at CSIRO, together with Johnson & Johnson Medical Devices Australia, are looking at new ways to address the challenges of motivating and assisting patients to complete rehabilitation programs while also reducing the communication gap that exist between clinicians and patients.

We have developed a digital orthopaedic rehabilitation platform for TKR, which comprises a mobile application (app), a wearable activity tracker, and a clinical web portal. The purpose built app includes behavioural coaching, practical hints and tips for surgical preparation, video based exercise demonstrations, and tools for self-monitoring of daily activities including progress collected through the activity tracker.

The app transmits patient-gathered data to a purpose built web portal where clinicians can view patient progress and configure exercise programs remotely.

A study will evaluate efficacy of the TKR platform through a randomised controlled trial (RCT) conducted with over 260 patients undergoing TKR surgery at multiple sites in a number of states in Australia. The trial will run for a period of 13 months for each patient.

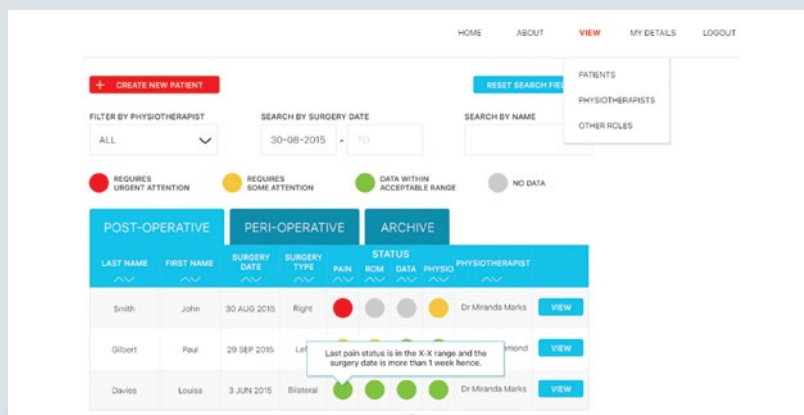


Figure 3. Activate TKR clinical portal: view all patients status and progress. The web portal allows clinicians (e.g., surgeons, physiotherapists) to view patient data and configure exercise programs for individual patients.

## EVALUATION OF BUTTERFLY SYSTEMS SOLUTIONS

Butterfly Systems has developed mobile applications (apps) to support the appropriate management of surgeons' preference cards which are fundamental to facilitate the flow of surgical instruments and materials to the surgical areas. Supported by a Commercialisation Acceleration grant, the Butterfly Systems will test these apps in multiple hospitals around Australia.

The Australian eHealth Research Centre at CSIRO is providing guidance to the Butterfly Systems during the development and execution of their trial, while also assisting with the evaluation study design, data analysis and report.

This project brings together our evaluation and human computer interaction expertise to guide the Butterfly Systems technology trial. We have developed a comprehensive evaluation framework which aims to understand the impact of the digital preference cards on clinical efficiency, accuracy of surgical item data and stock requirements as well as staff work practices.

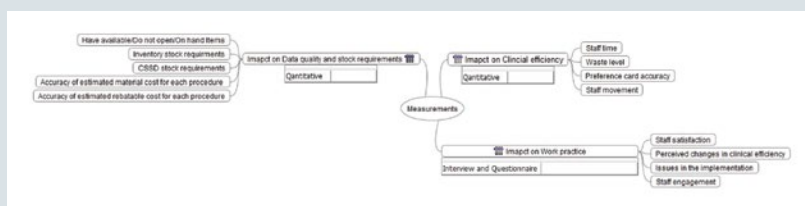


Figure 4. Measuring the impact of the digital surgeons' preference cards

## WORK IT OUT

To prevent and manage chronic conditions in urban Indigenous Australians, the Institute for Urban Indigenous Health (IUIH) has developed a range of programs including Deadly Choices and Work It Out. The Work It Out program is a face to face chronic disease management and rehabilitation program designed to empower Indigenous Australians to manage a range of chronic conditions such as diabetes and cardiovascular disease.

The Australian eHealth Research Centre at CSIRO is partnering with IUIH and Aboriginal and Torres Strait Islander participants of the Work It Out Program to develop and trial a mobile health platform to support the Work It Out program. This includes tailoring a health mobile application (app) to record diet, exercise and lifestyle factors on participants' mobile phones, developing a digital version of the Work It Out program for mobile delivery and customising a clinical portal to allow exercise physiologists to view daily data in order to guide and support participants in developing autonomy in healthy practices.

Figure 6. The Work It Out program is a face to face program delivered by the Institute for Urban Indigenous Health. Digital delivery of the program with an accompanying health app is aimed at further fostering implementation of healthy practices in every day life and improving health autonomy.

## FOODTRACK

FoodTrack™ is a comprehensive food and nutrient database developed through a collaboration between the Australian eHealth Research Centre at CSIRO and the Heart Foundation. It supports the collection and monitoring of nutrition and product data for foods and beverages in Australian supermarkets. The database contains highly accurate product data from fresh and packaged foods in major Australian supermarkets such as product descriptors (category, manufacturer, pack size), nutrition panel (NIP) information, ingredient lists, front-of-pack labels, images of the product and other relevant information, including multipacks and products with multiple NIPs. The FoodTrack™ platform comprises three key components; an intelligent mobile application (app), a cloud-based database and a web-portal to access and audit the data collected. Since its launch in 2014, the importance and relevance of FoodTrack™ has been immediate with the Heart Foundation, together with CSIRO, being engaged by the Federal Government to independently monitor the implementation of the voluntary front-of-pack labelling system – the Health Star Rating system, using the FoodTrack™ database. In 2015, FoodTrack™ received the INFOODS Success Stories Award for significant food composition achievements by the Food and Agriculture Organization of the United Nations.



Figure 5. FoodTrack logo



## ENGAGEMENT AND EFFECTIVENESS *(continued)*

### COLLABORATORS:

- Johnson and Johnson Medical AU
- Butterfly Systems
- Institute for Urban Indigenous Health
- The Project Factory
- Movember
- Melbourne Genomics Health Alliance

### PREFERENCES OF PATIENTS FOR INTERACTING WITH GENOMIC INFORMATION

Australia's health services and medical research organisations are currently undertaking a number of projects to prepare Australia for genomic medicine. These initiatives are already demonstrating how genomics can be used effectively in clinical medicine to improve patient outcomes and reduce health costs. An integral part of the integration of genomics into everyday care will be the provision of accurate, reputable information and resources for clinicians, patients and researchers.

As part of the Melbourne Genomics Health Alliance, CSIRO sought to determine the views of patients and parents of patients of the information the MGHA provided to them through a patient portal, information leaflets and a website. We found that participants were interested in interacting with their genomic information through a patient portal, and were keen to have additional resources that would allow them to gather the knowledge necessary to understand their genomic information, and the implications of that information for them and their families.

They identified a need for well-illustrated information of varying complexity provided at specific time points, and highlighted the importance of addressing mental health and wellbeing in all resource material.

Genomic medicine is already being integrated into everyday health care, understanding consumer needs will identify any barriers to engagement with genomic information and ensure that the most benefit is derived for patients and their families. The challenge will be in tailoring resources for a use by a diverse population throughout their genomic journey.

### PROJECT AIMS FOR 2016/17:

- Commence clinical trial for Activate TKR program
- Complete Review of Butterfly Systems technology
- Complete trial of Work it out at (location)

### PHD STUDENT PROFILE

#### Name: Jane Li

TOPIC: DESIGNING COLLABORATIVE WORKSPACES FOR PARTICULAR WORK SETTINGS.

Her supervisor is Professor Toni Robertson, director of Interaction Design and Human Practice Lab at UTS. Her thesis investigates how new collaboration technology can be designed to support real-time communication and information sharing between different teams across distinct local settings.

It was explored through three case studies in three work domains: multidisciplinary medical team meetings in two hospitals, collaboration in a national committee responsible for the emergency response to animal disease, and scientific collaboration across containment barriers in a biosecurity laboratory. Workplace studies were conducted within the context of developing collaborative workspaces.

The findings reveal how variations in local physical settings, information sharing practices and organizational contexts can influence the dynamics of collaboration and highlight different levels of configuration work required. A set of design guidelines has been developed for the design of collaborative workspaces while respecting variations within local practices.

## CARDIHAB

Cardihab Pty Ltd is AEHRC's first spin out company and was incorporated in February 2016 to commercialise the remote cardiac rehabilitation research conducted by AEHRC and Metro North HHS. Cardihab is currently being incubated as part of CSIRO's ON Innovation Program after completing two accelerator programs during FY 2015/16: CSIRO's AcceleratiON and HCF Catalyst.



Figure 1: Cardihab logo

### ACCELERATION

In July 2015 CSIRO introduced the "ON" program to provide research teams with an opportunity to develop and test a commercial model for their research as a way of delivering more value and impact from research. One element of "ON" is the AcceleratiON – a three month, structured program with fortnightly residential days. All CSIRO staff were eligible for the program. Team Cardihab, which consisted of AEHRC's Simon McBride, Dr Marlien Varnfield and Satu Marjomaa, along with CSIRO commercialisation manager Leonore Ryan, was fortunate to be one of nine teams competitively selected from 155 applications to join AcceleratiON Cohort 1.

Over 12 weeks the AcceleratiON teams were introduced to lean startup practices such as the business model canvas, the conduct of effective customer interviews, pitch development and delivery, and capital raising processes. The teams received intensive coaching around effective business planning, pitching and networking. Team Cardihab completed more than 100 customer development interviews in investigating customer value propositions and alternative business models in Australia and the USA.



Figure 2: Day 1 of HCF Catalyst: Cardihab with other teams and Slingshot staff.

The program concluded in a public 'Demo Night' where each team is showcased to more than 500 attendees including multinational corporations, large Australian enterprises and SMEs, government, investors and universities. Selected Cohort 1 teams, including Team Cardihab, were also invited to apply for incubation funding to continue focussed business development activities.



Figure 3: Cardihab AcceleratiON Team (L-R): Simon McBride, Dr Marlien Varnfield, Leonore Ryan and Satu Marjomaa.

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

# NATIONAL TELE-HEALTH TRIAL

## HOME MONITORING OF CHRONIC DISEASE: NATIONAL TELEHEALTH TRIAL

The CSIRO National Telehealth Trial was funded by the Commonwealth Government Telehealth Pilot Program and the CSIRO with additional in-kind support provided by clinical and industry partners. The project was a \$5.2m study conducted in 6 sites covering 5 states in Australia trialled for 18 months followed by a comprehensive data analysis and evaluation which was completed in May 2016.

The objectives of this project was to develop and implement a robust Before and After Controlled Intervention (BACI) methodology with a limited number of subjects, to investigate healthcare and socio-economic outcomes as well as organisational and workplace factors that may need to be considered in any large scale deployment of telehealth services for the management of patients with chronic conditions nationally.

Patients had no difficulty using the telehealth equipment, incorporated it easily into their daily lives and tended to monitor their vital signs and respond to questionnaires on average every two days. This generated a unique longitudinal record of the patient's health status, which with the application of simple predictive analytics could facilitate the better coordination of care, the reduction of unnecessary healthcare costs, reduced hospitalisation and reduced length of stay.

Care coordination was undertaken by clinicians at each trial site. Models of care were broadly identified as being hospital based (ACT and TAS) or community based (NSW, QLD and VIC). Normal care for patients enrolled in the study was provided through their regular GP.

The care coordinated approach to monitoring chronic disease patients in their home utilised in this trial is broadly illustrated below in Figure 1.

This project analyses and documents the effects of introducing at home telemonitoring of vital signs for the management of a heterogeneous group of chronically ill patients. Patients suffering from a wide range of chronic conditions, classified broadly as cardiovascular, respiratory or diabetes, who were frequently admitted to hospital, were selected from nominated hospital lists and other participating health services.

Patients were selected from Hospital lists who satisfied our clinical criteria, from ACT Health, Townsville Mackay LHD, North Tasmania LHD (Launceston) and Ballarat. Patients were also recruited from the Djiwarrah Health Service in Melton and ARV (Anglican Retirement Villages) in Penrith.

The target was to monitor 150 patients each with at least one control for a period of at least one year. These targets were not achieved because of delays associated with a lower than expected deployment of NBN services in the target sites, the need to obtain Human Research Ethics Committee clearances from eight different organisations and delays in identifying patients and gaining their consent as well as that of their GP. 114 Test patients and 173 Control patients were consented but some patients were lost because of missing PBS and MBS data. Final numbers were 100 Test patients and 137 control patients.

The impact of telemonitoring was analysed using a wide range of health and wellbeing outcomes as well as numerous health economic metrics derived from MBS and PBS data and Hospital Health Roundtable data. Data was also recorded from the telemonitoring system used in the trial, and a range of clinical questionnaires. The impact of this intervention on the patients, carers and clinicians involved in their care was quantitatively and qualitatively analysed and documented.

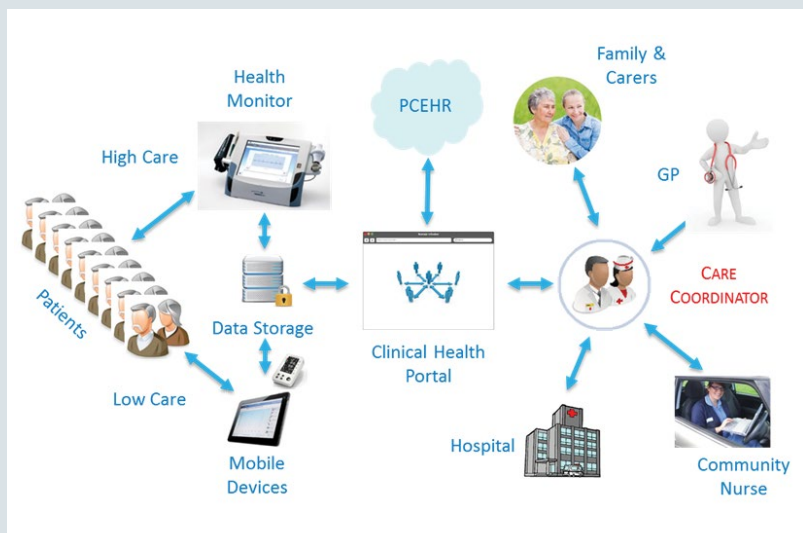


Figure 1: Care coordinated approach to monitoring chronic disease patients in their home

## NATIONAL TELE-HEALTH TRIAL *(continued)*

MBS and PBS data was analysed for approximately three years before the intervention and over one year after the intervention. This emphasised the impact of the intervention and reduced the possible impact of seasonal and other variables. Data was generally time-varying as all parameters (MBS and PBS expenditure as well as hospital admissions and length of stay) increased over time as a function of increasing age and morbidity. Linear regression and analysis of covariance, as well as Linear Mixed Effects (lme) modelling was used to identify statistically significant changes in slope before and after the intervention. These methods were applied to Test and Control patient data as well as to differences (Test-Control).

Highlights of the results obtained in this pilot program, using linear regression models and projections from before and after data, after one year of telemonitoring include;

- Primary health care services (MBS) fell by 24% over the first year: which is a 46.3% reductions in rate of MBS expenditure over one year.
- Unscheduled admissions to hospitals fell by 36% over the first year: Which is a 53.2% reduction in the rate of admission to hospital over one year
- Length of stay when admitted to hospital fell by 42% over the first year: Which is a 75.7% reduction in the rate of length of stay over one year
- > 40% reduction in mortality over the period of the trial.
- > 83% user acceptance and use of telemonitoring technology.
- > 89% of clinicians would recommend telemonitoring services to other patients

These results are broadly in agreement with other international data, but the impact of telemonitoring on MBS and PBS expenditure hasn't been reported previously.



Figure 2: Telehealth trial patient Jack Fernihough taking his daily measurements

In addition, this project reports on the effect of workplace culture and capacity for innovation and organisational change management in successfully integrating a new model of care with long established service models. We have demonstrated that the success metrics for the deployment of telehealth services relate more to on-site clinical leadership, capacity to accommodate change and the flexibility of existing processes and systems than any technical issues associated with the telehealth monitoring equipment or patient adherence to measurement schedules.

An economic analysis of the impact of telehealth was undertaken based on the results of this trial and the experience of establishing telehealth services in six diverse sites in Australia. An operational model based on a single Clinical Care Coordinator managing 100 patients is proposed for future large scale deployments of Telehealth. This trial suggests that for chronically ill patients, an annual expenditure of \$2,760 could generate a saving of between \$16,383 and \$19,263 pa, representing a Return on Investment (ROI) of between 4.9 and 6.0.

A number of clinical partners in the CSIRO National Trial are continuing to carry out telemonitoring of patients with chronic conditions, funded from internal efficiency dividends and are exploring funding models to expand the services to much larger numbers of patients.

### Patient Case Study

Jack Fernihough, a participant in the trial, attributed the telehealth technology to saving his life. The monitoring system picked up the early signs that his heart was under increased stress, which allowed him to receive lifesaving surgery.

"In April this year I had a triple bypass and without the monitor we wouldn't have known that there was anything seriously wrong," Mr Fernihough said.

"It found out things about my heart that I wouldn't have known about until it was too late and I'd probably be gone by now," he said.

## AUSTRALIAN TELE-HEALTH RESEARCH AND DEVELOPMENT GROUP



### DIRECTOR: YOGI KANAGASINGAM

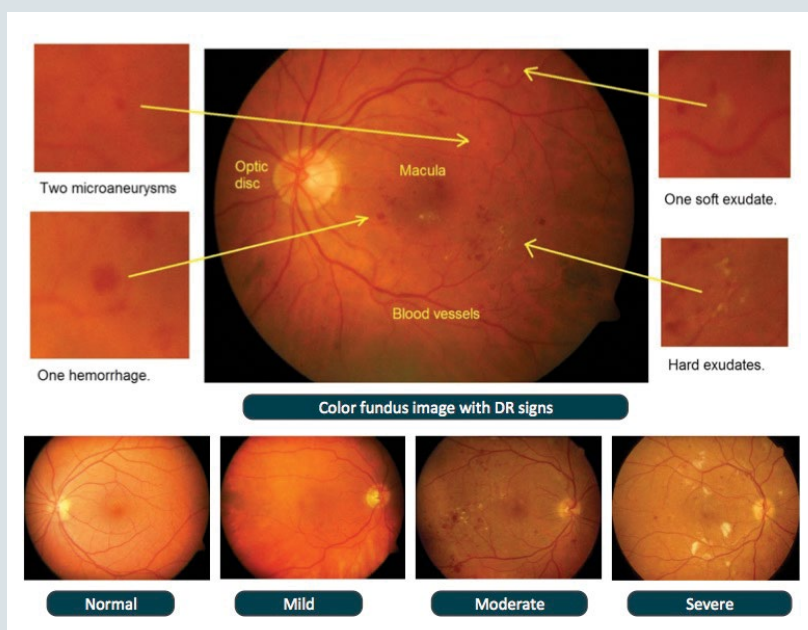
The Australian Tele-health Research and Development Group is our partnership with the Western Australian Department of Health and our Western Australia node of the Australian e-Health Research Centre (AEHRC). The three year grant from the Department of Health was renewed from July 2015 for a further three years.

The ATRDG aims to be a world leading Telehealth research and development group. The research and development program aims to transform the way health services are delivered 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 aim of this research has been to improve health outcomes in Western Australia and increase the productivity and efficiency of health service delivery in Western Australia.

There are three research key areas:

- Remote Delivery of Clinical Services – supporting health services and clinicians by using telemedicine and related technology to develop new ways of delivering health services.
- Chronic Disease Management – using mobile phone based chronic disease monitoring and home based care to provide services directly to patients.
- Disease diagnosis and screening technologies – developing new, mostly ocular, screening technologies for early detection of Alzheimer's disease, stroke, mental health disorders and hypertension.

## REMOTE DELIVERY OF CLINICAL SERVICES



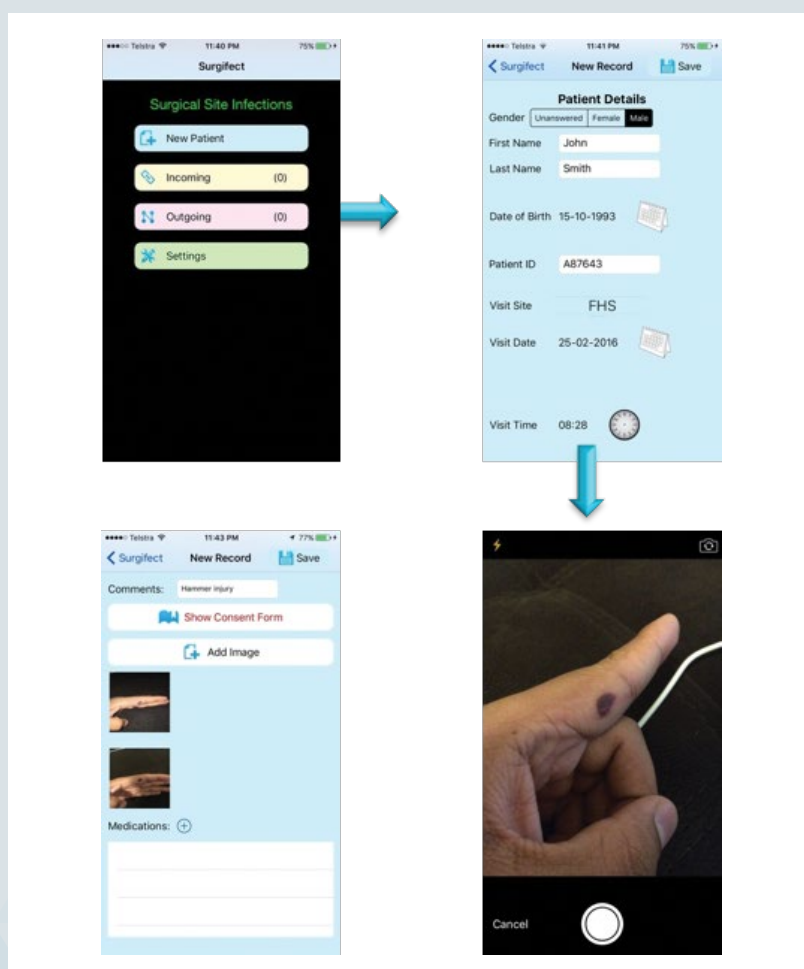
### AUTOMATIC DISEASE GRADING SYSTEM FOR DIABETIC RETINOPATHY

The have obtained a NHMRC development grant to develop and validate a smart eye screening system for early detection of DR. As part of the project we have developed a image quality control system to identify those images which are not of good quality for automated grading system. We have developed the algorithms and evaluated the system based on a training data set of 200 patients. Our grading system is also able to grade the disease as mild, moderate or severe such that referral or no-referral indication could be given to the screeners.

We received a sensitivity and a specificity over 85% which is equivalent to human accuracy. At present, we are setting up the field trial to test the system in real time. We will start the clinical trials in Sept 2016 at GP clinic in Perth.

### MEDICAL IMAGE COMMUNICATION AND EXCHANGE (MICE) APP FOR BURNS PROJECT DESCRIPTION:

Using the Medical Imaging and Communication Exchange App, junior doctors, specialists and nurses can now get expert real time diagnostic advice about various conditions by securely sending wound/burns images through the mobile device. By way of streamlining the medical image capture and storage process, the app introduces a secure way of sending medical images to a specialist. Images captured through the app are not saved on the mobile device and only the specialists and related doctors can see them. Medical records and images are managed through our award winning store and forward telehealth system (Remote-I). This system can be accessed via web or mobile and maintains secure access rights for all the users.



**COLLABORATORS:**

- Prof Fiona Wood (Australian of the Year), Director, Burns Unit at the Fiona Stanley Hospital
- WA Health

**HIGHLIGHTS FOR 2015/16:**

- Diabetic Retinopathy grading system evaluation on training data set completed
- Image quality control system evaluation completed
- App development finalised for iOS (iPhones)
- Preliminary evaluation completed by the technical staff at Burns Unit

**AIMS FOR 2016/17:**

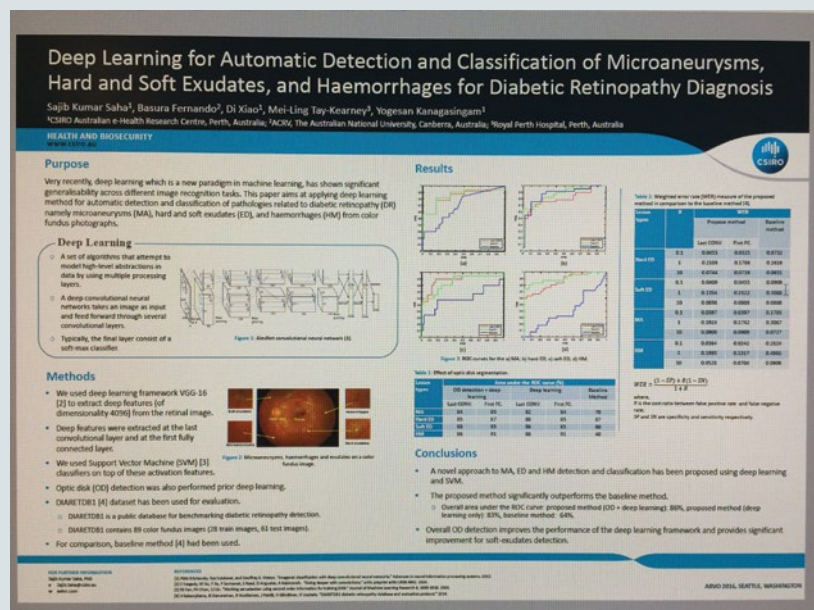
- Conduct a clinical trial of diabetic retinopathy grading system in the field at a GP clinic
- Obtain sensitivity and specificity of the grading system based on the field trial
- Clinical trial of the MICE app by the specialists and junior doctors at Fiona Stanley Hospital
- Publish the trial outcomes in high impact journals
- Apply for funding to expand the application to other medical applications (e.g. wounds, dermatology)
- Explore opportunities to commercialise and bring the product to market licensing or spin-off options.

**POSTDOCTORAL FELLOW****Name: Sajib Saha, PhD**

TOPIC: DEEP LEARNING TECHNIQUES TO STUDY THE LONGITUDINAL CHANGES IN RETINAL VASCULATURE

Dr. Sajib Kumar Saha joined CSIRO in August 2015 as a postdoctoral fellow and working towards the development of machine learning techniques for the automated detection and progression analysis of sight threatening eye disease, specifically diabetic retinopathy (DR). During this time he has proposed a deep learning based DR detection method, leading to a paper in ARVO 2016. ARVO papers are included in the IOVS journal (IF: 3.47).

Dr Saha has developed a novel retinal image registration method and an automated image quality assessment method for DR screening. This has led to the establishment of a collaboration with the University of California, Berkeley and Stanford University in California to use their retinal image dataset and to develop novel methods for the analysis of disease progression. Dr. Saha is also working with researchers from the Khulna University in Bangladesh.



## CHRONIC DISEASE MANAGEMENT

This stream of work at the ATRDG includes research on how telehealth can be used to assist in the management of complex and chronic conditions in the home. Here, ATRDG is collaborating with the Mobile Health team to develop Western Australian arms of the mobile health trials currently underway elsewhere. An existing trial of automated data collection and alerts for chronic obstructive pulmonary disease patients will be expanded with a multi centre study from Perth, Brisbane and Melbourne. We are also working on a mobile phone based cardiac rehabilitation project in WA for the Indigenous population.

### COLLABORATORS:

- COPD: Dr Yuben Moodley, Fiona Stanley Hospital (Respiratory Physician)
- Cardiac Rehabilitation: Dr Sandy Hamilton, Western Australian Centre for Rural Health, UWA
- Cardiac Rehabilitation: Prof Sandy Thompson, Western Australian Centre for Rural Health, UWA

### AIMS FOR 2016/17:

- Chronic Obstructive Pulmonary Disease (COPD): A preliminary study was conducted on 10 patients to use automated patient data collections and alerts to improve care delivery. The preliminary study will be expanded by the ATRDG, using a new version of Mobile Technology enabled Rehabilitation (MoTeR), developed by the Australian e-health Research Centre for COPD, to include 50 patients in a follow-on multi-State trial. We will submit a grant proposal for a multi centre study.
- Cardiac rehabilitation: A NHMRC partnership grant has been submitted by the Western Australian Centre for Rural Health and if successful we will kick start the project from Jan 2017. We will also recruit a PhD student to work on this project.

## DISEASE DIAGNOSIS AND SCREENING TECHNOLOGIES

In this stream of work the ATRDG is exploring ways to develop biomarkers to screen and diagnose diseases early such that appropriate treatment and surgery could be provided in a timely manner. Our focus has been studying the changes related to vascular parameters from the retina and the anterior segment in relation to various diseases development such as stroke, hypertension, Alzheimer's disease, heart disease and mental disorders. All data collection have been done in partnership with different clinics from Perth.

### OCULAR BIOMARKERS FOR ALZHEIMER'S DISEASE

ATRDG has been developing ocular biomarkers for early detection of Alzheimer's disease. The goal of the study is to see if a non-invasive and inexpensive eye test can detect people on the pathway to Alzheimer's disease. The trial involves two visits by volunteers to the McCusker Alzheimer's Research Foundation, where they will have their eyes tested using retinal image fluorescence photography. Between appointments, volunteers take a curcumin supplement. Curcumin is a natural ingredient used in cooking; it 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, then we will have the makings of a screening tool for Alzheimer's. It may enable us to identify people very early in the development of the disease, which could enhance our ability to intervene and stop or delay Alzheimer's progression.

All our clinical data collection have been completed by march 2016 – baseline study of 200 patients completed, longitudinal study of 100 patients completed, Young controls study of 20 patients completed. We are now working with Neurovision imaging (NVI – California, USA) on the data analysis.

### Ocular biomarkers for Mental health disorders

This is a collaborative research project between Hollywood Private Hospital and ATRDG. The research project will investigate whether the retina can allow specialists to more effectively detect and monitor brain disorders such as post-traumatic stress, anxiety, eating disorders, major depression and alcohol dependence. Research will include identifying eye biomarkers that are specific to different disorders and determine if they can predict the success of different treatments.

These questions will be addressed using retinal photography, optical coherence tomography and pupillometry. We already know that there are multiple structural and physiological disturbances of the eye related to schizophrenia, and we are eager to learn what else the retina can tell us about other disorders and their treatments. We believe the retina may provide a window to detect and monitor brain disorders. As a developmental outgrowth of the brain, the eye provides central nervous system access through live, non-invasive optical imaging with great detail. Unfortunately for sufferers, current methods of diagnosis are complex and subjective, therapeutic options are limited, and misdiagnosis may often occur. We hope that this study will help to resolve these issues.

Data collection is done by the Hollywood Hospital clinicians as their in-kind support.



Figure1: Retinal photo obtained during the stroke trial at the Royal Perth Hospital

## DISEASE DIAGNOSIS AND SCREENING TECHNOLOGIES *(continued)*

### RETINAL BIOMAKERS TO PREDICT STROKE

Improvements in acute care of stroke patients have decreased mortality, but survivors are still at increased risk of future vascular events and mitigation of this risk requires thorough assessment of the underlying factors leading to the stroke. The brain and eye share a common embryological origin and numerous similarities exist between the small vessels of the retina and brain. Recent population-based studies have demonstrated a close link between retinal vascular changes and stroke, suggesting that retinal photography could have utility in assessing underlying stroke risk factors and prognosis after stroke.

The retinal microvasculature is highly accessible, with modern imaging equipment facilitating precise measurement and monitoring of vascular features. However, use of this equipment is a challenge in the stroke ward setting as patients are frequently unable to maintain the required seated position, and pupil dilatation is often not feasible as it could potentially obscure important neurological signs of stroke progression. This pilot study investigated the utility of a novel handheld, non-mydratic retinal camera in the stroke ward, and explored associations between retinal vascular features and stroke risk factors. This camera circumvented the practical limitations of conducting retinal photography in the stroke ward setting.

A positive correlation was found between carotid disease and both mean width of arterioles ( $r = 0.40$ ,  $p = 0.00571$ ) and venules ( $r = 0.30$ ,  $p = 0.0381$ ). The results provide further evidence that retinal vascular features are clinically informative about underlying stroke risk factors, and demonstrate the utility of handheld retinal photography in the stroke ward.

#### COLLABORATORS:

- Neurovision Imaging, Sacramento, California
- Hollywood Private Hospital (Ramsay Health Care)
- Royal Perth Hospital

#### PROJECT HIGHLIGHTS FOR 2015/16:

- All data collection for biomarker development for Alzheimer's disease has been completed
- One publication of the results have been submitted: Shaun Frost, et al., Alzheimer's disease and the early signs of age-related macular degeneration, Current Alzheimer Research, June 2016,
- Media coverage of our Mental Health research work lead to more than 100 patients calling us to participate in the trial. We will recruit about 200 patients for this study.
- The Stroke study has been concluded with 90 patients who had first stroke have been screened. The results are analysed and an article has been sent for publication.

#### AIMS FOR 2016/17:

- We will start a new clinical trial with new imaging technology and protocols
- Screen more than 200 mental health patients and start analysing the data before end of June 2017
- As the stroke clinic at Royal Perth Hospital has been closed and moved to Sir Charles Gairdner Hospital we will be seeking to establish similar study with a new cohort
- Redefine the stroke study to explore people with secondary stroke

# AEHRC PUBLICATIONS 2015-16

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## BOOK CHAPTERS

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### Dr Olivier Salvado, Group Leader

Ms Denis Bauer, Bioinformatics  
Dr Pierrick Bourgeat, Research Scientist  
Mr Sam Burnham, Statistician  
Mr David Conlan, Senior Software Engineer  
Dr James Doecke, Statistician  
Dr Vincent Dore, Research Scientist  
Dr Jason Dowling, Research Scientist  
Dr Nicholas Dowson, Research Scientist  
Dr Amir Fazlollahi, Postdoctoral Fellow  
Dr Jurgen Frapp, Research Scientist  
Dr Tim Kahlke, Postdoctoral Fellow  
Dr Ales Neubert, Postdoctoral Research Fellow  
Dr Kerstin Pannek, Postdoctoral Fellow  
Dr Parnesh Raniga, Research Scientist  
Prof Stephen Rose, Senior Principal Research Scientist  
Dr Kaikai Shen, Postdoctoral Research Fellow (WA)  
Mr Bill Wilson, Bioinformatics  
Dr Laurence Wilson, Postdoctoral Fellow  
Mr Julian Heinrich (transferred to Data61, January 2016)  
Dr Sean O'Donoghue (transferred to Data61, January 2016)  
Ms Zoe van Havre, Statistician  
Dr Firoz Anwar, Postdoctoral Fellow  
Mr Kirill Frolov, Industrial Trainee

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### Dr Mohanraj Karunanithi, Principal Research Scientist

Dr Shlomo Berkovsky, Research Scientist  
Dr Dana Bradford, Research Scientist  
Dr Hang Ding, Research Scientist  
Dr Farhad Fatahei, Postdoctoral Fellow  
Dr Jill Freyne, Senior Research Scientist  
Dr Shaun Frost, Biomedical Scientist (WA)  
Dr Sazzad Hussain, Postdoctoral Fellow  
Dr David Ireland, Postdoctoral Fellow  
Ms Jane Li, Research Scientist  
Mr Simon McBride, Research Consultant  
Mrs Maryam Mehdizadeh, Project Officer  
Dr Ghassem Mokhtari, Postdoctoral Fellow  
Mr Aidan O'Brien, Research Project Officer  
Dr Sajib Saha, OCE Postdoctoral Fellow  
Dr Marlien Varnfield, Postdoctoral Research Fellow  
Mr Janardhan Vignarajan, Software Engineer (WA)  
Dr Di Xiao, Research Scientist (WA)  
Prof K Yogesan, Research Director (WA)  
Dr Shuang Yu, Postdoctoral Fellow  
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Mr Christopher Bell, The University of Queensland  
Ms Marcela Cespedes, Queensland University of Technology  
Ms Amy Chan, The University of Queensland  
Mr Amir Fazlollahi, University of Burgundy, France  
Mr Ashley Gillman, The University of Queensland  
Mr Hamed Hassanzadeh, The University of Queensland  
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Mr Alex Pagnozzi, The University of Queensland  
Mr Anthony Paproki, The University of Queensland  
Mr Lee Reid, The University of Queensland  
Ms Zahra ShahabiKargar, Griffith University  
Ms Ying Xia, The University of Queensland

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Madison Kelly, Griffith University  
Samuel Damen, The University of Queensland  
Liam Heiniger, The University of Queensland  
Gurunath Iyer, The University of Queensland  
Paul Alvino, The University of Adelaide

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Dr Charles Baker, The University of Queensland  
Dr Jose Manjon, Universidad Polit cnica de Valencia (Spain)

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Finance – Rebecca Mok and Kellie Tighe  
HR – Laurie Mackenzie and Justine Potter  
Project Support – Katie Forrestier  
Contract Support – Rebecca Walls  
HSE Support – Sandra Kay  
Business Development Support – Dr Peter Kambouris

# **SPECIAL PURPOSE FINANCIAL REPORT**

**30 JUNE 2016**

**THE AUSTRALIAN E-HEALTH RESEARCH CENTRE**  
(AN UNINCORPORATED JOINT VENTURE)

Detailed financial information from pages 69-76 have been  
deliberately omitted from this report.

## 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 2016 and its performance for the year ended on that date in accordance with the terms of the joint venture agreement and the accounting policies described in Note 1 to the financial statements.

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



Director

Brisbane

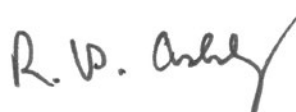
Date: 29/8/16



Director

Brisbane

Date: 29/8/16



Director

Brisbane

Date: 29.8.16



Director

Brisbane

Date: 29/8/16

## INDEPENDENT AUDITOR'S REPORT

### TO THE DIRECTORS OF THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

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 2016, 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.

#### Directors' Responsibility 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.

#### Auditor's Responsibility

Our responsibility is to express an opinion on the financial report based on our audit. We conducted our audit in accordance with Australian Auditing Standards. Those standards require that we comply with relevant ethical requirements relating to audit engagements and plan and perform the audit to obtain reasonable assurance about whether the financial report is free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial report. The procedures selected depend on our judgment, including the assessment of the risks of material misstatement of the financial report, whether due to fraud or error. In making those risk assessments, we consider internal controls relevant to the entity's preparation and fair presentation of the financial report 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 entity's internal controls. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of accounting estimates made by the directors, as well as evaluating the overall presentation of the financial report.

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

#### Independence

In conducting our audit we have complied with the independence requirements of the Australian professional accounting bodies.

#### Opinion

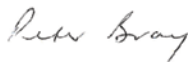
In our opinion, the financial report presents fairly, in all material respects, the financial position of The Australian E-Health Research Centre as of 30 June 2016 and its financial performance and its cash flows for the year then ended in accordance with the accounting policies described in Note 1 to the financial statements.

#### Basis of Accounting and Restriction on Distribution

Without modifying our opinion, 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.



Trumans



Peter Bray  
Partner

Chatswood

Dated: 2 September 2016



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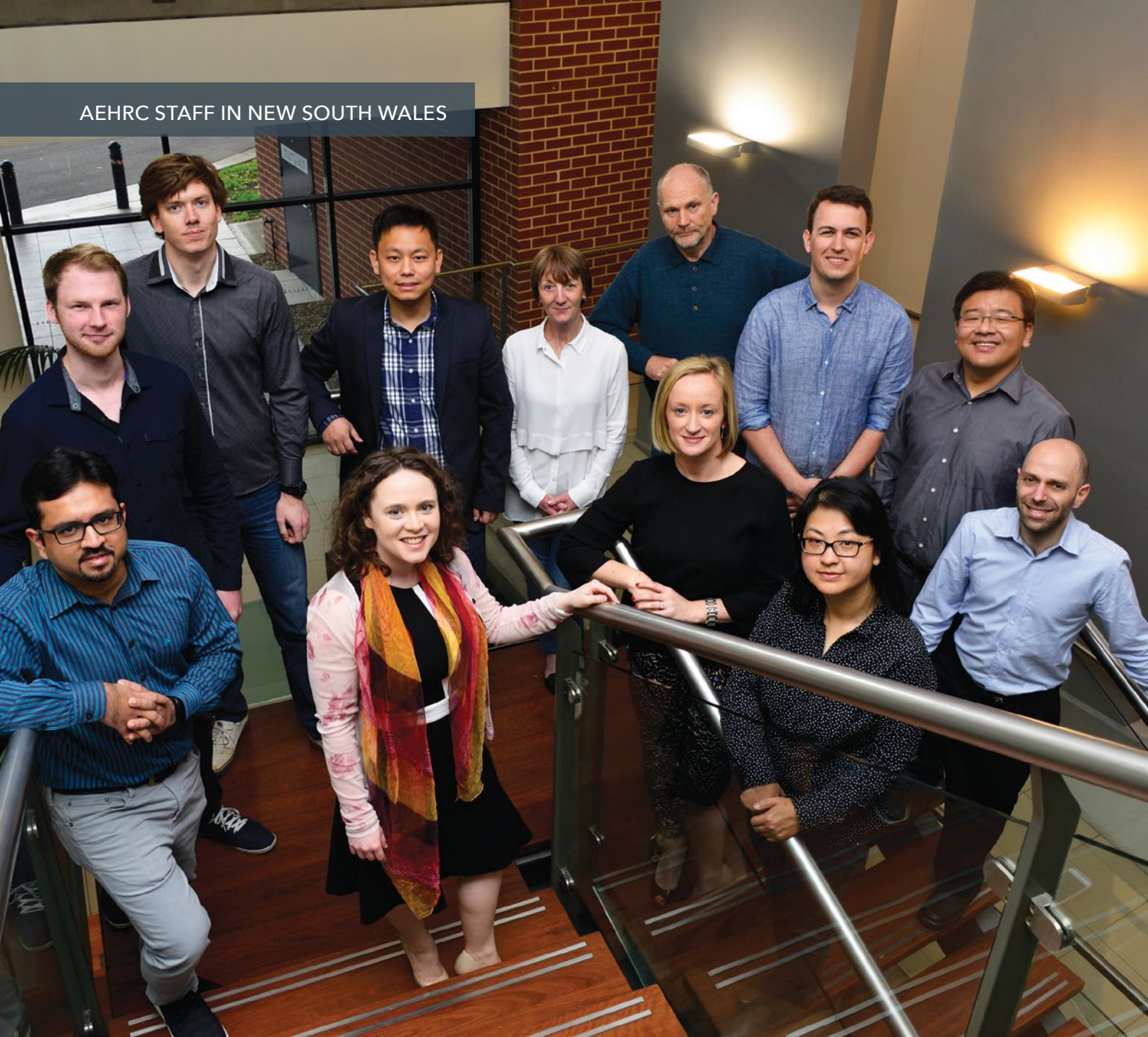
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AEHRC STAFF IN NEW SOUTH WALES



AEHRC STAFF IN VICTORIA





# THE AUSTRALIAN **E**HEALTH RESEARCH CENTRE

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## **Acknowledgments**

Editorial: **Dr David Hansen**, *the Australian e-Health Research Centre*  
**Marie Dwyer**, *the Australian e-Health Research Centre*

