A new prescription

PREPARING FOR A HEALTHCARE TRANSFORMATION

ATSE
Australian Academy of
Technology & Engineering

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Report of a study by the Australian Academy of Technology and Engineering (ATSE)

STEERING COMMITTEE
Professor Hugh Bradlow FTSE, Mr Phil Butler FTSE, Mr Drew Clarke AO PSM FTSE,
Professor Mark Dodgson AO, Mr Michael Edwards FTSE, Ms Kathryn Fagg AO FTSE,
Emeritus Professor Simon Foote FAA FTSE FAHMS, Dr Erol Harvey FTSE,
Ms Sue MacLeman FTSE and Mr David Thodey AO FTSE

EXPERT WORKING GROUP
Emeritus Professor Simon Foote FAA FTSE, Dr Carrie Hillyard AM FTSE,
Dr Cherrell Hirst AO FTSE, Dr Anna Lavelle FTSE, Ms Sue MacLeman FTSE,
Dr George Morstyn FTSE, Dr Tracie Ramsdale FTSE, Dr John Ramshaw FTSE,
Professor Karen Reynolds FTSE, Professor John Skerritt FTSE,
Professor Greg Tegart FTSE and Professor Alan Trounson FTSE

PROJECT TEAM
Ms Jasmine Francis, Ms Riajeet Kaur, Ms Robyn Lawford, Dr Michelle Low,
Dr Matt Wenham and Ms Alix Ziebell.

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Telephone +61 3 9864 0900 Facsimile +61 3 9864 0930
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Ms Elizabeth Geddes
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Project Steering Committee

- Professor Hugh Bradlow FTSE (ATSE President; former Chief Scientist, Telstra)
- Mr Phil Butler FTSE (Chairman, Textor Technologies)
- Mr Drew Clarke AO PSM FTSE (Chair, AEMO; Director CSIRO & NBN; former Secretary Energy and Communications Departments); Steering Committee Co-Chair
- Professor Mark Dodgson AO (Professor of Innovation Studies, University of Queensland / Imperial College London)
- Mr Michael Edwards FTSE (General Manager, Boeing Research & Technology Australia)
- Ms Kathryn Fagg AO FTSE (Board Member, Boral), Steering Committee Co-Chair
- Dr Erol Harvey FTSE (Head of Strategy and Research Translation, Bionics Institute)
- Mr David Thodey AO FTSE (Chair, CSIRO Board; former CEO, Telstra)

Project Expert Working Group

- Emeritus Professor Simon Foote FAA FTSE (Emeritus Professor, The John Curtin School of Medical Research, The Australian National University); Expert Working Group Co-Chair
- Dr Carrie Hillyard AM FTSE (Chairman, Leukaemia Foundation, Director, Fitgenes Australia Ltd)
- Dr Cherrell Hirst AO FTSE (CEO and Deputy Chair, Lifesciences Venture Capital Fund QIC BioVenture)
- Dr Anna Lavelle FTSE (Chairman, Medicines Australia)
- Ms Sue MacLeman FTSE (Chair and Non-Executive Director, MTPConnect); Expert Working Group Co-Chair
- Dr George Morstyn FTSE (Director, Actinogen Medical Ltd)
- Dr Tracie Ramsdale FTSE (Director, Anatara Lifesciences)
- Dr John Ramshaw FTSE (The University of Melbourne; former Chief Research Scientist, CSIRO)
- Professor Karen Reynolds FTSE (Professor of Biomedical Engineering, Flinders University)
- Professor John Skerritt FTSE (Deputy Secretary for Health Products, Department of Health)
- Professor Greg Tegart FTSE (Adjunct Professor, Victoria University)
- Professor Alan Trounson FTSE (President, Hudson Institute of Medical Research)

Project Team

Ms Jasmine Francis
Ms Riajeet Kaur
Ms Robyn Lawford
Dr Michelle Low
Dr Matt Wenham
Ms Alix Ziebell

COVID-19

The research for this report was completed before the outbreak of the COVID-19 pandemic. A short case study has been added to the final publication. See pages 33-34.

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Abbreviations

3D	Three-dimensional
4D	Four-dimensional
5G	Fifth-generation of mobile network
ACOLA	Australian Council of Learned Academies
ACSC	Australian Cyber Security Centre
ADHA	Australian Digital Health Agency
AEMO	Australian Energy Market Operator
ACCHO	Aboriginal Community Controlled Health Organisations
AI	Artificial intelligence
AIDS	Acquired immunodeficiency syndrome
AM	Member of the Order of Australia
AMA	Australian Medical Association
AO	Officer of the Order of Australia
ARC	Australian Research Council
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ASD	Australian Signals Directorate
ATSE	Australian Academy of Technology and Engineering
Australian Genomics	Australian Genomics Health Alliance
BTF	Biomedical Translation Fund
CAR-T	Chimeric antigen receptor T-cell
CEO	Chief Executive Officer
CLG	Centre for Law and Genetics
COAG	Council of Australian Governments
COVID-19	The 2019 novel coronavirus
CRC-P	Cooperative Research Centres Program
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CT	Computed tomography
DEA	Doctors for the Environment Australia
DHS	Department of Human Services
ECG	Electrocardiogram
EHR	Electronic health records
EMR	Electronic medical record
EMRAM	Electronic Medical Record Adoption Model
FAA	Fellow of the Australian Academy of Science
FAHMS	Fellow of the Australian Academy of Health and Medical Sciences
FAICD	Fellow of the Australian Institute of Company Directors
FIPAA	Fellow of Institute of Public Administration Australia, Victoria
FASSA	Fellow of the Academy of Social Sciences in Australia
FDA	Food and Drug Administration (United States)
FHIR	Fast Healthcare Interoperability Resources
FTSE	Fellow of the Australian Academy of Technology and Engineering
GAICD	Graduate member of Australian Institute of Company Directors
GDP	Gross domestic product
GP	General practitioner

HIE	Health Information Exchange
HIMSS	Health Information and Management Systems Society
HISA	Health Informatics Society of Australia
HIV	Human immunodeficiency viruses
ICT	Information and communications technology
In vivo and ex vivo	In and out of the living (Latin)
IoMT	Internet of Medical Things
IoT	Internet of Things
IT	Information technology
LASP	Learned Academies Special Project
LHN	Local Hospital Network
MBS	Medicare Benefits Schedule
MedTech	Medical technology
MERS	Middle Eastern respiratory syndrome
mHealth	Mobile health
MHR	My Health Record
MRFF	Medical Research Future Fund
MRI	Magnetic resonance imaging
NBN	National Broadband Network
NGFW	Next-generation firewalls
NHMRC	National Health and Medical Research Council
OECD	Organisation for Economic Co-operation and Development
PCEHR	Personally controlled electronic health record
PET scan	Positron emission tomography scan
PHN	Primary Health Network
PHR	Personal health records
PSM	Public Service Medal
PwC	PricewaterhouseCoopers
QUT	Queensland University of Technology
R&D	Research and development
RFID	Radio frequency identification
RFDS	Royal Flying Doctor Service
SARS	Severe acute respiratory syndrome
STEM	Science, technology, engineering and mathematics
TALEN	Transcription activator-like effector-based nucleases
TGA	Therapeutic Goods Administration
T-VEC	Talimogene laherparepvec
UN	United Nations
UQ	University of Queensland
US	United States
UV	Ultraviolet
VET	Vocational and educational training
VR	Virtual reality
Wearables	Wearable technology
WHO	World Health Organisation
ZFN	Zinc finger nucleases

Glossary of terms

Assistive technologies
The World Health Organisation (WHO) defines these as technologies whose primary purpose is to maintain or improve an individual's functioning and independence to increase participation and wellbeing, as well as to improve health outcomes.[2]

Chronic disease
Chronic diseases are long-lasting health conditions that can have significant physical, social and financial effects on an individual's quality of life. While chronic disease can refer to a number of conditions, this report focuses on the most prevalent chronic conditions for Australians, including allergy, cancer, cardiovascular disease, overweight and obesity, and mental illness.

Consumers and patients
These are the users (end-users) or customers of the healthcare system, services and technologies. A consumer tends to participate in decision-making, while a patient tends to receive care without necessarily taking part in decision-making.[3]

Digital and data technologies
These are electronic systems, software, devices or tools that capture, store, analyse or generate data. For the purposes of this report, 'digital and data technologies' is used as an umbrella term to encompass information communication technologies (ICT), health informatics, advanced computational technologies (artificial intelligence, robotics, genomics), mobile health and telehealth tools, and remote-care technologies.

Emerging diseases

These are diseases that have recently been recognised, introduced or are newly evolved; or diseases that have recently and rapidly changed in incidence or expansion in terms of geographical, host or vector range.[4] Examples of emerging diseases include acquired immuno-deficiency syndrome (AIDS), severe acute respiratory syndrome (SARS), Middle Eastern respiratory syndrome (MERS), Ebola virus disease, chikungunya, Nipah virus, H1N1 pandemic influenza, H5N1 influenza and Zika virus.[5]

Interoperability

Interoperability is the ability of different information systems, devices and applications to access, exchange, integrate and cooperatively use data in a coordinated manner, within and across organisational, regional and national boundaries, to provide timely and seamless portability of information and optimise the health of individuals and populations globally.[6]

Integrated care

The Royal Australasian College of Physicians defines integrated care as the organisation and delivery of healthcare services to provide seamless, coordinated, efficient and effective care that meets all of an individual's needs. In practice, integrated care involves collaboration and cooperation between providers and healthcare services across all levels of care, inclusive of primary care providers, specialists, hospital services and allied health professionals.[7]

Megatrends

Megatrends are the overarching social, economic, environmental, technological and geopolitical forces that shape the future of industries.[8] They often cause disruption to existing business models and subsequently present significant opportunities and challenges for organisations.[8]

Medical technology

Examples of medical technology (MedTech) include automation, drug and vaccine design, patient medical records, remote healthcare, machine learning, and wearables and sensors.

Personalisation of healthcare

Personalisation of healthcare refers to the increasing involvement of individuals in the design and delivery of their healthcare, for the purpose of empowering patients, improving health outcomes and promoting health and wellbeing.

Precision medicine

Technologies broadly encompassing omics (genomics, proteomics, metabolomics, microbiomics, etc.), epigenetics, and gene and cell therapies are used to develop tailored therapies for a personalised response to disease.[9]

Re-emerging and persistent diseases

These are diseases that have historically infected humans, and that continue to appear and reappear in new locations or in drug-resistant forms after apparent control or elimination.[9] Examples of re-emerging diseases include dengue fever, cholera, methicillin-resistant staphylococcus aureus (MRSA), drug-resistant tuberculosis and drug-resistant malaria.[4]

Executive summary

Executive summary

Australia needs a new prescription for healthcare — specifically, a focus on prevention and wellness, enabled by technology. While the healthcare system has delivered increased life expectancies and improved quality of life for several decades, these successes have also thrown up new challenges. Healthcare in Australia is under strain, and nowhere is this more obvious than in the poor outcomes associated with chronic illnesses such as obesity, mental illness and cardiovascular disease.

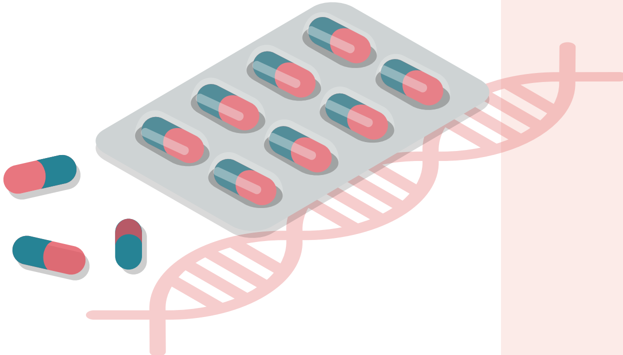
The rising burden of chronic conditions is one of several critical challenges the healthcare sector will face in the coming decade. Other challenges include changes in consumer behaviour and expectations, incompatible record-keeping systems, poor communication between healthcare professionals, inequity in access to care and unsustainable funding models. To effectively tackle these challenges the sector must undergo a step change, embrace technology and shift its focus to prevention and wellness, radically moving from reactive to preventative strategies.

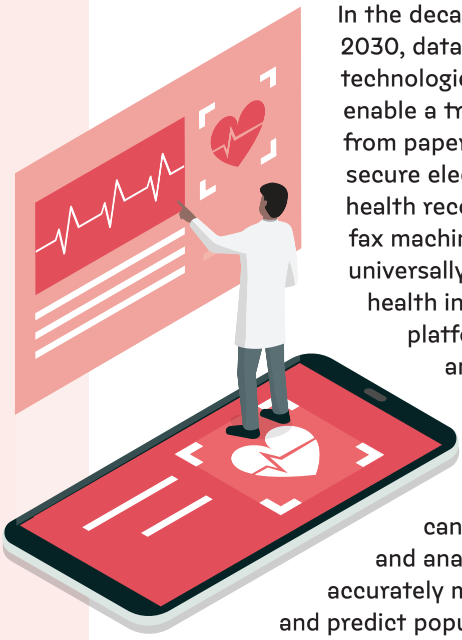
Australia's healthcare system remains one of the best in the world, and our life expectancy for both men and women is among the highest globally.

Research and stakeholder consultations revealed a consistent and common theme: the current system of healthcare delivery is fragmented, inefficient and unsustainable. We must use technology to support a shift in focus to a patient-centred, outcomes-focused, value-based system of healthcare delivery.

Drawing on its experience as a Learned Academy of independent, non-political experts dedicated to helping Australians understand and use technology to solve complex problems, the Australian Academy of Technology and Engineering (ATSE) has examined the healthcare sector's readiness to develop, adapt and adopt technologies that will underpin this shift over the next ten years. In preparing this report, we have also drawn on the expertise of key stakeholders from the nation's healthcare sector. This work has been conducted as part of a three year, Australian Research Council-funded project identifying research and policy priorities for technology readiness in different Australian industry sectors.

Through ATSE's analysis, a roadmap for essential change emerged.





DIGITAL & DATA
In the decade to 2030, data and digital technologies will enable a transition from paper files to secure electronic health records; from fax machines to universally accessible health information platforms; and from fragmented information to big data that can be mined and analysed to accurately map, monitor and predict population health trends. Technology will integrate patient histories, with an individual's electronic health records functioning as a shared resource between themselves and their general practitioner (GP), hospital, specialist, pharmacist and other healthcare professionals.

PRECISION MEDICINE
Precision medicine will become more common, with prevention and treatment strategies targeted to individuals. Genetic testing and screening for preventable disease will also become an affordable option.

INTEGRATED CARE
Healthcare will become integrated through technology, with smart devices, mobile health and telehealth – all linked through a digital health record – enabling a holistic picture of a person's health. Technological solutions to the problems of distance and mobility will enable affordable healthcare access for more Australians, when and where we need it.

We have a long way to go before this vision of a technology-supported healthcare system becomes a reality, but ATSE's analysis shows that it is achievable by 2030. Work is already underway in all the critical areas. However, in some of these areas, we will need to do more, or make faster progress.

Australia's social and ethical readiness for new health technologies is high, as is our policy and regulatory readiness. ATSE's research and consultations show that as a nation we are prepared for a technology-supported transition – in fact, we expect it, although we have concerns about cybersecurity and ethics. Regulatory structures for the transition are debated in the sector, but most agree they are heading in the right direction.

Greater preparation is required in our infrastructure, workforce skills, and economic and commercial environment. The infrastructure is being readied, both physically and digitally, but this work is not progressing rapidly enough; the sector's workforce has not kept pace with changes in digital and other emerging healthcare technologies; and medical technology (MedTech) and pharmaceutical researchers do not always possess the necessary skills to translate breakthroughs into commercial success. Our healthcare system is also funded to provide episodic care, and there are no incentives to focus on patients and their best long-term health outcomes.

ATSE's findings were tested through the Academy Fellowship and with key stakeholders in government and the healthcare sector. The summary readiness results of this analysis are shown below in Table 1.

TABLE 1
Readiness assessment

SCALE	NOT READY	MORE WORK REQUIRED			READY
READINESS INDICATOR SCALE	○	◔	◑	◕	●

ASSESSMENT					
	Infrastructure & systems readiness	**Skills availability**	**Social & ethical readiness**	**Economic & commercial feasibility**	**Policy & regulatory readiness**
Digital & data technologies	◑	◔	◔	◑	◔
Precision medicine	◑	◑	◑	◔	◕
Integrated care technologies	◔	◔	◕	◔	◑

The most critical priority is the digitisation of health records – an issue that was highlighted by the majority of stakeholders and underpins the technology solutions identified by ATSE. Without a shift to electronic records, the fragmented healthcare system will not cope with increased volumes of data and the emergence of digital technologies, nor with the increasing personalisation of healthcare. Integrated care will be unachievable without electronic health records, which are essential for efficient, accurate, timely and patient-centred care.

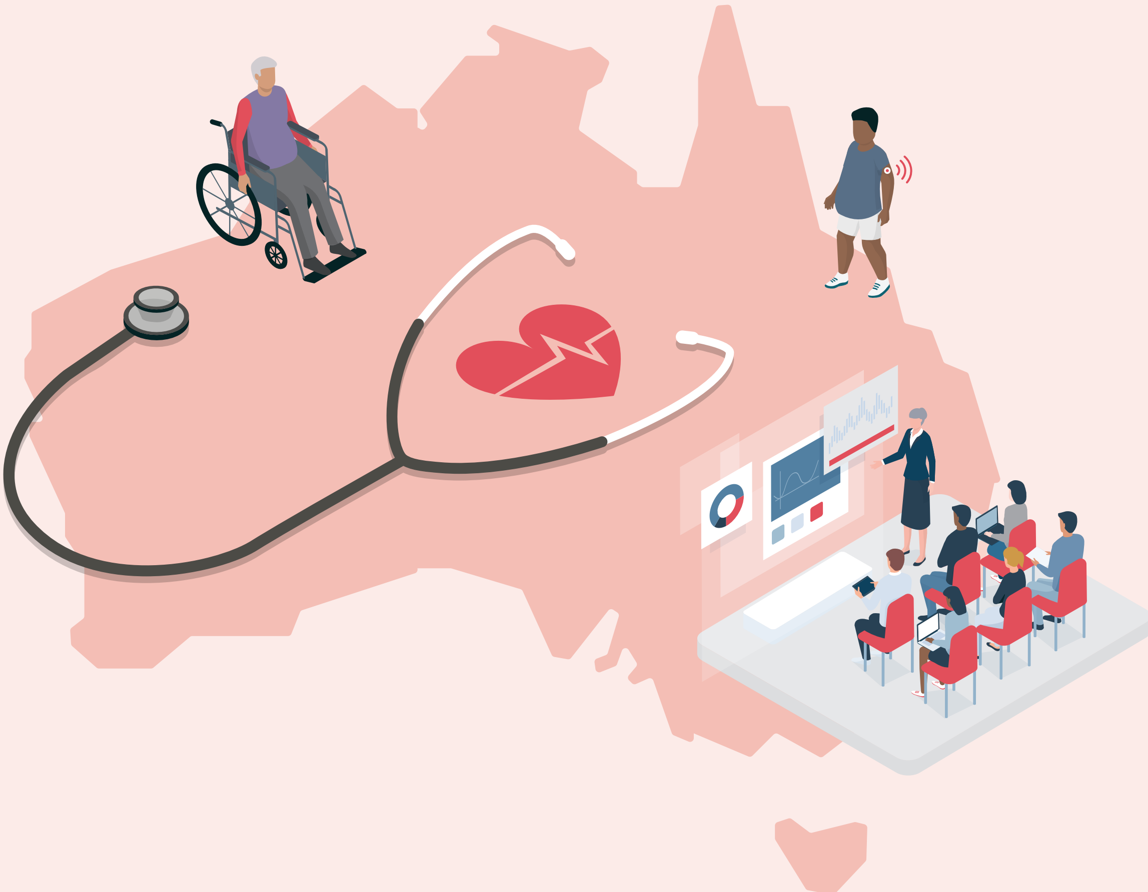
Embracing new technologies will also be vital in ensuring that the benefits of a wellness system are available in regional areas and Aboriginal and Torres Strait Islander communities, and to disadvantaged people in urban communities. Barriers to equitable outcomes include distance, communication difficulties, financial resources, education levels, accessibility, and shortages of healthcare workers. Mobile and telehealth services can easily and inexpensively help Australians overcome these obstacles and access the best available care in a timely way.

Empowering the workforce to maximise the benefits from new healthcare, data and communications technologies will result in increased efficiency, better decision-making and improved outcomes. The workforce must be supported in its transition to a focus on prevention and wellness, particularly developing skills to adapt to a technology-driven workplace.

Finally, the research sector needs a boost to provide the healthcare system with the tools it needs and ensure a robust return on investment. Despite generous government support, Australia's position as a world leader in health technology research is at odds with its poor translation and commercialisation record, indicating a system failure. Government has a responsibility to ensure that there is support for – and a clear path to develop – timely, cost-effective and commercially successful products from initial research outcomes.

ATSE has developed four headline recommendations to address these themes, along with supporting recommendations and research priorities to catalyse and use technology to underpin the healthcare sector's transition. These recommendations are intended as guidelines for government, funding agencies, the healthcare sector and the research community to meet the needs and expectations of diverse Australian communities, and to build practical research agendas to address questions about our future healthcare system.

This report provides an opportunity to plan for the future of healthcare in Australia, using technology to support our health and wellness. Australia is a global leader in health, but it is critical that we continue to identify what we want for our society, what action government and the healthcare sector need to take, and how this will translate to a healthcare sector of the future.



RECOMMENDATION 1

Transition to interoperable electronic health records.

All healthcare providers must switch to electronic records as soon as possible. Social licence for this move will fundamentally depend on well-communicated privacy and cybersecurity frameworks.

To underpin this transition, ATSE makes the following recommendations.

RECOMMENDATION 1.1
Conversion to electronic health records should be mandatory for all healthcare providers in Australia.

To support this shift:

a. The Australian Government should lead the development of interoperability standards for digital health. These should include data collection, sharing and security standards, building on work conducted by the Australian Digital Health Agency (ADHA) to implement the National Digital Health Strategy deliverables on interoperability and secure messaging.

b. A public campaign should be launched to improve take-up and awareness of electronic health records, developed in consultation with stakeholders within the healthcare sector, and including patient perspectives.

c. Patients should retain the choice to opt out of having their information shared to a personal health record, such as My Health Record.

RECOMMENDATION 1.2
To build social licence, the Australian Government should develop a national framework to strengthen health data privacy and usage, building on experience managing health privacy under the Privacy Act 1988, and in response to the Productivity Commission's Inquiry into Data Availability and Use.

The framework should include:

a. Centralised, easily available information about existing rights and regulations, including in the information-sharing mechanisms between third parties

b. Clarity around people's rights to control, correct and determine access to their own health data, and that of dependents

c. Authorisation for aggregated, anonymised clinical and laboratory data to be available for research quality control and benchmarking

RESEARCH PRIORITIES

Research priority 1.1
How can existing and new technologies be integrated within different health settings or contexts? How do we 'join up' the health data ecosystem?

Research priority 1.2
How can we best build public confidence in digital health technologies?

Research priority 1.3
How can we shift perspective to value data, rather than regarding it as a burden?

RECOMMENDATION 2

Improve equity of access to healthcare through technology.

Use of telehealth and AI-enabled devices must increase to support equitable outcomes for people living with disadvantage. These technologies can be used to improve access and reduce financial burden.

To improve equity of access to healthcare for all Australians, ATSE makes the following recommendations.

RECOMMENDATION 2.1
The Australian Government should incentivise the adoption of technologies designed to improve equity of access to healthcare across the country's vast distances and diverse communities.

Priority should be given to technologies that support integrated care models, such as:

a. Wearable monitors, apps, secure transmission of prescriptions and referrals, and AI-assisted reminders and scheduling
b. An integrated, standards-based telehealth platform applicable across multiple domains, including home telemonitoring, home tele-rehabilitation, residential care facilities, general practices, mental health support, community health centres and remote medical services

RECOMMENDATION 2.2
The healthcare sector should expand its adoption of mobile technologies for prevention, diagnosis, treatment, monitoring and support.

Mobile health can be used effectively as a low-cost intervention in prevention, and to deliver healthcare services to people when and where they need them.

a. Expansion of mobile health technologies will require agile, adaptive regulation. Additional resources will be needed for the Therapeutic Goods Administration to monitor and anticipate emerging technologies.

RESEARCH PRIORITIES

Research priority 2.1
How do remoteness, financial and cultural factors affect uptake of new health technology by patients and healthcare providers?

Research priority 2.2
What can be done to ensure health data is appropriately representative of minority groups in the population?

RECOMMENDATION 3

Support the existing and future healthcare workforce in the transition.

Existing and new members of the national healthcare workforce must be supported and empowered to retrain, adapt and develop skills in line with the requirements and benefits of new digital technologies.

RECOMMENDATION 3.1
All levels of government should provide ongoing support for the healthcare workforce to retrain, adapt and develop, in line with the National Digital Health Workforce and Education Roadmap under development by the ADHA. Qualifications and training must be agile and ongoing, supporting adaptation to changing technologies, roles and tasks.

RECOMMENDATION 3.2
Universities and vocational education and training (VET) institutions, in collaboration with industry and the professional peak bodies for healthcare providers, should create or modify courses and training options to include digital health literacy content in all health-related degrees.

RECOMMENDATION 3.3
Healthcare professional colleges and organisations that are responsible for continuous professional development should include new technologies and digital literacy in their curricula to upskill healthcare professionals via mechanisms such as micro-credentialing, short courses, industry secondments, mentoring and workplace exchange programs.

RECOMMENDATION 3.4
State and territory departments of education should strengthen the content and teaching of health literacy, digital literacy, and STEM.

RESEARCH PRIORITIES

Research priority 3.1
How do future skill, job, infrastructure and technology needs map on to existing incentives and accreditation processes?

Research priority 3.2
How will automation and AI affect the healthcare workforce, both current and future?

RECOMMENDATION 4

Provide targeted support for a thriving health technology sector.

Government must support investment in improving pathways to commercialisation for Australian-developed medical technology.

RECOMMENDATION 4.1
The Australian Government should take a strategic approach to funding areas of high potential growth with strong market need and commercial potential. Priority should be given to:

a. Proposals in which strong science addresses areas of validated and unmet need, where there is a clear commercial value proposition and competitive advantage for the product or service being developed.
b. Funding areas where government support can be leveraged to de-risk external investment.
c. Proposals with existing industry collaborations, or the potential for such collaborations.

RECOMMENDATION 4.2
Research institutions, including universities, should provide coaching on product development and commercialisation pathways to healthcare sector researchers, including intellectual property development and management, to ensure they can move from basic research funding to other investment attraction, and to more effective product development and translation where of interest.

a. This coaching should include assistance to develop a target product profile capturing the development and commercialisation path, along with a clear description of the unmet medical need (market size and structure) being addressed. It should also address the value proposition in the current and future competitive landscape, and the regulatory and market access strategy.
b. Research institutions should prioritise the attraction of suitably qualified people from industry to grow their translation and commercialisation expertise.
c. Research institutions should invest in upskilling technology transfer offices with stronger commercialisation skills, and should ensure that investment is in place for project capture and management.

RECOMMENDATION 4.3
Commercialisation success should be recognised and substantively taken into account when awarding peer-reviewed competitive grants, along with publication and patent records. This should involve the addition of commercially experienced members to all assessment panels.

RECOMMENDATION 4.4
Australian, state and territory governments should use their purchasing power to drive commercial opportunities, support innovation, and actively encourage value-based, preventative care, including through procurement and reimbursement systems.

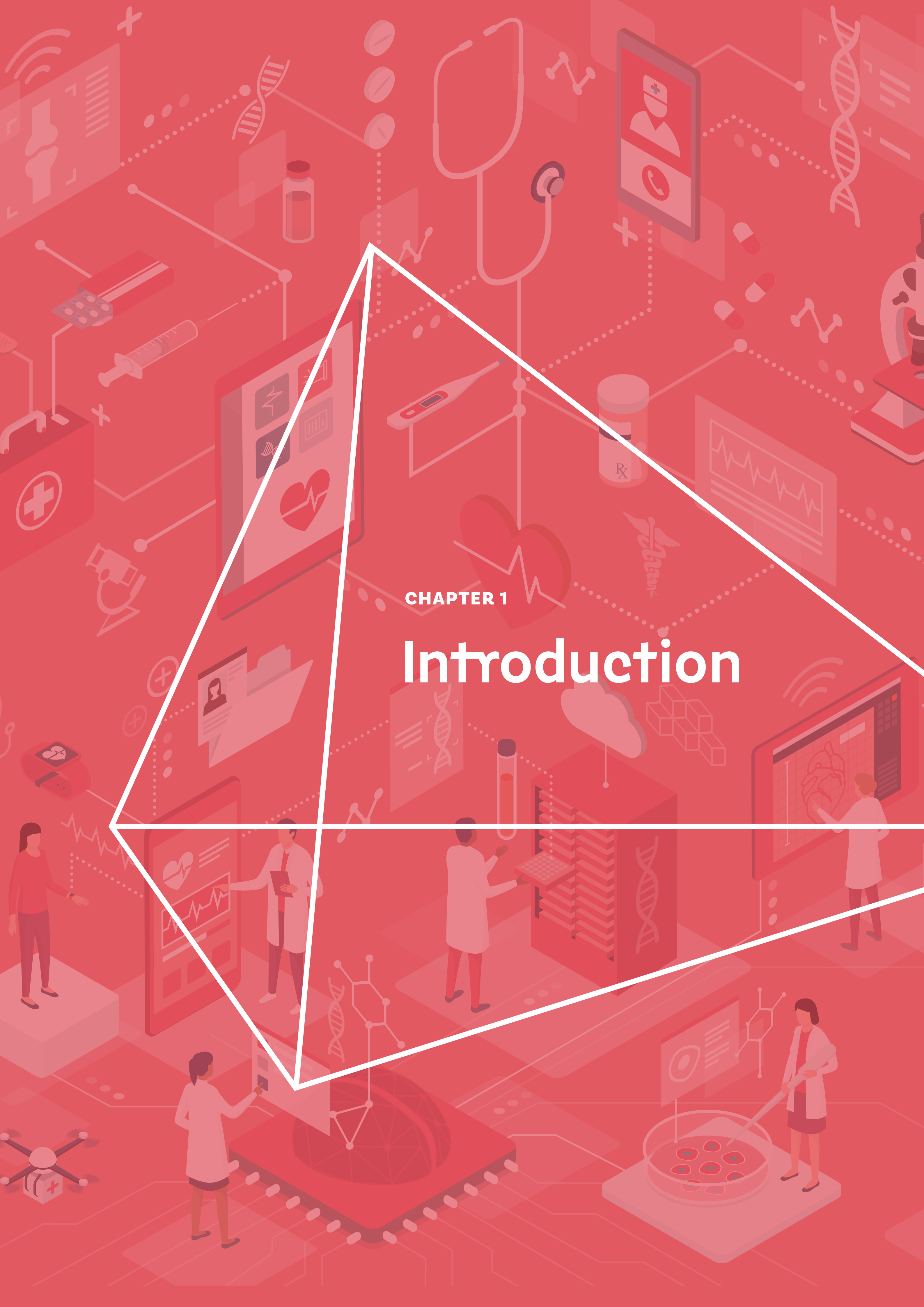
RESEARCH PRIORITIES

Research priority 4.1
How can international best practice in policy and regulatory and investment frameworks be applied in an Australian setting to support and encourage the translation and commercialisation of healthcare and medical research?

Research priority 4.2
What government support would provide access to investment, skills and global supply chains?

CHAPTER 1

Introduction



CHAPTER 1

Introduction

Australia's healthcare system remains one of the best in the world, and our life expectancy for both men and women is among the highest globally. However, Australia's health outcomes are poor in a number of areas, particularly chronic illnesses such as obesity, mental illness and cardiovascular disease. Our healthcare sector also faces critical challenges in the coming decade, including the rising burden of chronic disease, changing consumer behaviour and expectations, fragmented healthcare systems and records, inequity in access to healthcare and care experiences, unsustainable funding models and adjustment to an increasingly digital world.

To meet these challenges, our healthcare sector must embrace technology and shift the focus of healthcare delivery to prevention and wellness. This will reduce the frequency and burden of illness, strengthen the sustainability of our healthcare system, increase healthy life years for the Australian population, and empower people to make choices about their own health.

The Australian Academy of Technology and Engineering (ATSE) has examined the readiness of Australia's healthcare sector to use technology in this transition as part of a major, three-year research project (2018–20). Over the course of this project, ATSE is examining the readiness of Australian industry sectors to develop, adapt and adopt new and emerging technologies to meet the challenges they face in the decade to 2030. The project aims to identify key policy recommendations for technology adoption and impact, and develop a roadmap for research over the coming decade.

ATSE is a Learned Academy of independent, non-political experts who help Australians to understand and use technology to solve complex problems. We have drawn on this experience and on the expertise of key stakeholders from Australia's healthcare sector to prepare this report. The project is primarily funded via an Australian Research Council (ARC) Learned Academies Special Projects (LASP) grant.

1.1. OBJECTIVES

This report aims to provide a roadmap for prioritisation of high-value, high-impact technology in the future of healthcare in Australia. The key objectives of this project are to:

OBJECTIVE 1

Identify existing and emerging technologies that will affect the healthcare sector over the coming decade to 2030, and determine which have the potential to deliver the greatest benefit.

OBJECTIVE 2

Examine the readiness of the healthcare sector to adopt, adapt or develop these technologies to address key challenges in the decade to 2030, through research and targeted consultations with representatives from government, the healthcare industry and research.

OBJECTIVE 3

Provide advice and recommendations to policymakers, the healthcare sector and the healthcare industry on using technology to support the healthcare system to transition its focus to prevention and wellness.

OBJECTIVE 4

Highlight future research priorities to support the healthcare sector in its transition to focus on prevention and wellness in the decade to 2030, and into the future.

1.2 METHODOLOGY

In framing this project, ATSE identified four challenges that the Australian healthcare sector will face in the decade to 2030 for which the integration of health-related technologies would be disruptive and beneficial:

CHALLENGE 1 —— **The rising burden of chronic disease**

CHALLENGE 2 —— **Threats from emerging, re-emerging & persistent infectious diseases**

CHALLENGE 3 —— **Digital transformation**

CHALLENGE 4 —— **Increasing consumer expectations**

Within the framework of these challenges, the project identified existing and emerging technologies in prevention and wellness, diagnosis and monitoring, and treatment, recovery, rehabilitation and follow-up. The project then identified three technology platforms based on these enabling technologies, that can potentially support the healthcare sector to address challenges over the decade to 2030 and shift the focus of the healthcare system to prevention and wellness.

These three potential solutions are:

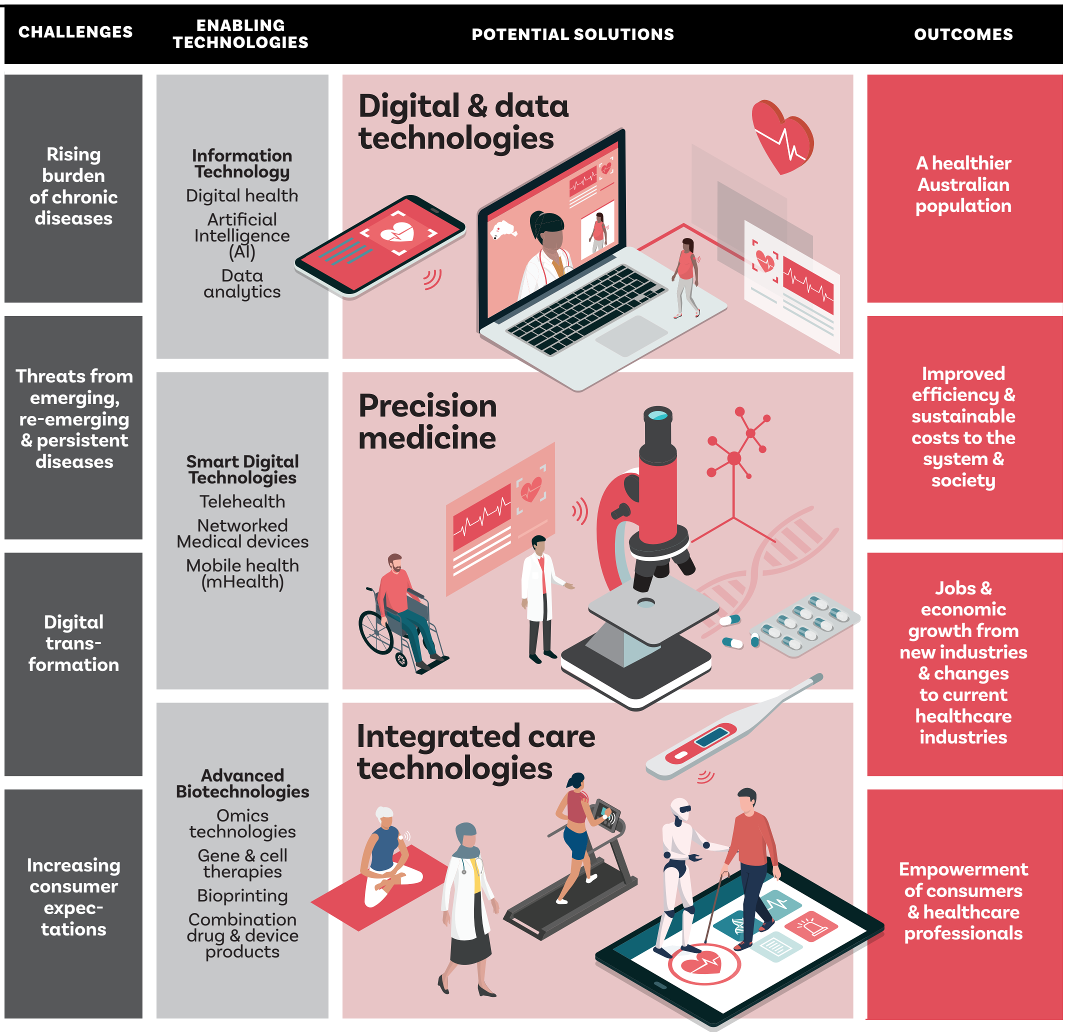
POTENTIAL SOLUTION 1 —— **Digital and data technologies**
Electronic systems, software, devices or tools that capture, store, analyse or generate data.

POTENTIAL SOLUTION 2 —— **Precision medicine**
The study of an individual's genetic and biochemical make-up (as formed by their genes, environment and lifestyle) to prevent, diagnose and treat health-related issues.

POTENTIAL SOLUTION 2 —— **Integrated care technologies**
A model of patient-centred care delivery that involves the organisation and delivery of healthcare services to provide seamless, coordinated, efficient and effective care that meets all of an individual's needs.

A representation of the complete analytical framework is shown in Figure 1. ATSE used this framework to develop its assessment of the healthcare sector's technology readiness.

FIGURE 1
Health technologies and systems to address key 2030 challenges



The report provides an assessment of the Australian healthcare sector's readiness to develop, adopt or adapt the potential technological solutions by examining five readiness parameters:

READINESS PARAMETERS

Infrastructure & systems readiness

Skills availability

Social & ethical readiness

Economic & commercial feasibility

Policy & regulatory readiness

ATSE's analysis was informed by significant research and widespread consultations with health stakeholders from across Australia, overseen by a Steering Committee and an Expert Working Group of ATSE Fellows. ATSE consulted with over 230 stakeholders through a survey, roundtable discussions and direct feedback. These stakeholders included representatives from the healthcare sector, the healthcare industry, government (including policymakers and regulators), the research sector, not-for-profit organisations, consumer bodies and healthcare industry associations with exposure to sector-wide technology readiness.

ATSE's findings and recommendations were tested through the Academy Fellowship and with key stakeholders in government, research and the healthcare industry. A summary of the analysis and detailed methodology is found in Appendix A, and the overall process is shown in Figure 2.

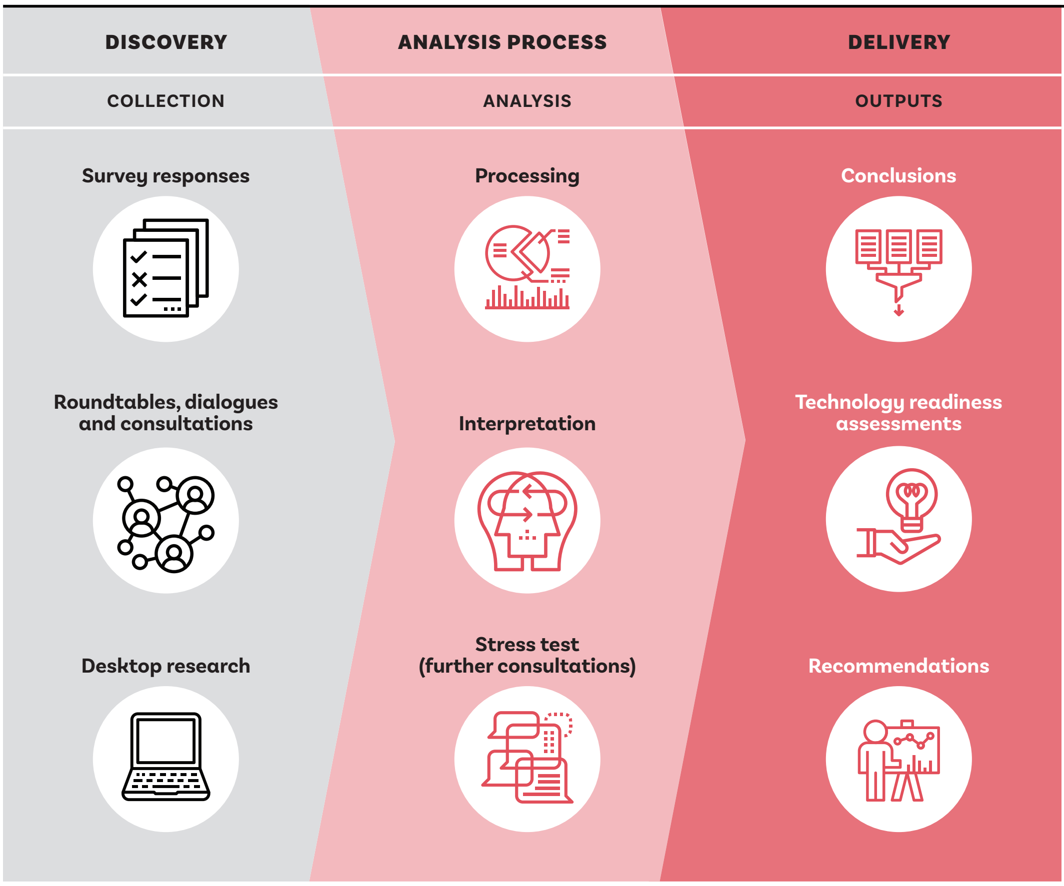


FIGURE 2
Project methodology used to generate ATSE's readiness indicators and recommendations

Readiness metrics were initially collected through a survey of healthcare sector stakeholders, compiled from over 100 responses. They were adjusted based on ATSE's analysis of desktop research and the views expressed in roundtable consultations conducted in Melbourne, Canberra, Brisbane and Sydney. These roundtables were critical in helping ATSE to understand the key factors enabling the uptake and integration of technology within the healthcare sector, and to highlight similarities and differences in opinions about technology readiness in the healthcare sector (discussed further in Chapter 4).

Key themes

1

CHANGE THE FOCUS TO PREVENTION AND WELLNESS

The current system of healthcare delivery is fragmented, inefficient and unsustainable. We must shift the focus to prevention and wellness, and to a patient-centred, outcomes-focused, value-based system of healthcare delivery.

2

HEALTHCARE MUST BE DIGITISED

There is a critical need to digitise healthcare. This process has already begun but is impeded by resistance to change in the healthcare sector and significant consumer mistrust.

3

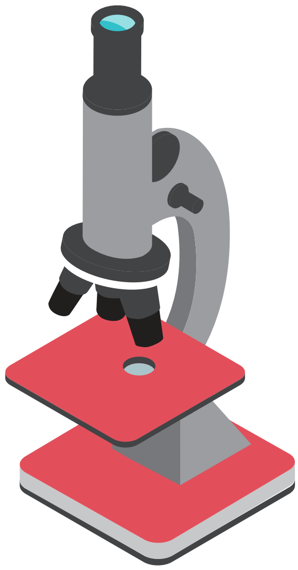
WORKFORCE NEEDS TO SKILL UP

Australia faces skills shortages, including in digital literacy in the healthcare workforce, and in research translation and commercialisation (for example, in the medical technology, biotechnology, digital health and pharmaceutical research sector).

4

ACCESS TO HEALTHCARE MUST IMPROVE ACROSS AUSTRALIA

Australia has a problem achieving equity in access to healthcare, particularly with regard to new technologies, which can be expensive and restricted to urban facilities.



Overall, stakeholders indicated that while a significant amount of work is already being done to improve Australia's technology readiness in the healthcare sector, more work will be needed over the next decade to ensure that Australia continues to be well placed to use technologies that will benefit the sector.

In particular, four key themes emerged throughout the consultations and in ATSE's own research:

- The current system of healthcare delivery is fragmented, inefficient and unsustainable. We must shift the focus to prevention and wellness, and to a patient-centred, outcomes-focused, value-based system of healthcare delivery.
- There is a critical need to digitise healthcare. This process has already begun but is impeded by resistance to change in the healthcare sector and significant consumer mistrust.
- Australia faces skills shortages, including in digital literacy in the healthcare workforce, and in research translation and commercialisation (for example, in the medical technology, biotechnology, digital health and pharmaceutical research sector).
- Australia has a problem achieving equity in access to healthcare, particularly with regard to new technologies, which can be expensive and restricted to urban facilities.

1.3. STRUCTURE OF THE REPORT

The remaining four chapters of this report provide an overview of the challenges facing the healthcare sector, explore some key health-related technologies, look at the application of these technologies, and discuss conclusions and recommendations to support the healthcare system's transition to prevention and wellness.

CHAPTER 2 provides an outline of key challenges – the overarching social, economic, environmental, technological and geopolitical forces that will disrupt and shape the future of the healthcare sector in the decade to 2030.

CHAPTER 3 reviews key enabling technologies in the healthcare sector: data technologies, smart digital technologies, medical technologies and advanced biotechnologies.

CHAPTER 4 discusses the readiness of Australia's healthcare sector to implement three potential technology platform solutions, analysing each of them against the five readiness parameters.

CHAPTER 5 provides ATSE's conclusions, recommendations and research priorities to support the healthcare system's transition to a focus on prevention and wellness through technology in the decade to 2030.

CHAPTER 2

Challenges

CHAPTER 2

Challenges

ATSE identified four key challenges that the Australian healthcare system will face in the decade to 2030, based on the extent to which the integration of health-related technologies would be disruptive and beneficial:

CHALLENGE 1 —— The rising burden of chronic disease

CHALLENGE 2 —— Threats from emerging, re-emerging & persistent infectious diseases

CHALLENGE 3 —— Digital transformation

CHALLENGE 4 —— Increasing consumer expectations

In nominating these as the key challenges, ATSE was informed by the health megatrends identified in MTPConnect's Medical Technology, Biotechnology and Pharmaceutical Sector Competitiveness Plan,[8] discussions at key stakeholder dialogues held in Melbourne and Canberra and advice from the project's Expert Working Group and Steering Committee.

2.1. THE RISING BURDEN OF CHRONIC DISEASES

A disease is defined as a physical or mental disturbance involving symptoms (such as pain or feeling unwell), dysfunction or tissue damage that may lead to ill health.[10] Diseases can be acute or chronic, or in some cases both.[10] Acute diseases tend to have a rapid onset and/or a short course and are typically brief, intense and/or severe.[10,11] In contrast, chronic diseases have complex and multiple causes. They are not usually considered immediately life threatening and are generally long-term and persistent diseases. Chronic diseases often lead to a gradual deterioration in health and loss of independence.[12]

Chronic diseases and conditions are on the rise worldwide.[13] Chronic conditions account for 87 per cent of deaths in Australia, and one in two Australians are estimated to have a chronic disease.[14] Heart disease, mental health conditions (such as depression) and cancer account for almost half of the disease burden in Australia, with obesity identified as a major risk factor for chronic diseases.[15] By 2030, mental health is expected to become the largest healthcare burden.[16] Factors linked to chronic diseases include poor diet and nutrition (including vitamin D deficiency), physical inactivity and inadequate sleep.[17,18] Minimising these factors may help to reduce the risk of chronic disease on an individual basis, and may reduce population-wide mortality from chronic disease.[14]

Chronic conditions account for 87 per cent of deaths in Australia, and one in two Australians are estimated to have a chronic disease.

Many chronic conditions occur across our lifetimes, although they become more prevalent with older age.[12] The proportion of people with more than one chronic disease also increases with age. Changes in societal behaviour and an ageing population are major contributors to the steady increase in the prevalence of chronic diseases in Australia. The leading cause of burden of disease for older Australians is coronary heart disease, followed by dementia and chronic obstructive pulmonary disease.[19] The top ten individual diseases among older Australians accounted for over half of the total burden of disease in Australia in 2011.[19]

Excess body weight is also a major risk factor for the development of cardiovascular disease, Type 2 diabetes, high blood pressure, sleep apnoea, psychological issues, some musculoskeletal conditions and some cancers.[20,21] Being overweight can hamper a person's ability to control or manage chronic disorders, and people who are overweight or obese have higher rates of death.[20] Overweight and obesity are major public health issues in Australia, with 63 per cent of Australian adults classified as overweight or obese in 2014–15.[22] In 2015, 8.4 per cent of the total burden of disease in Australia was due to overweight and obesity,[20] and the prevalence of severe obesity in Australia has nearly doubled from 5 per cent in 1995 to 9 per cent in 2014–15.[10] The cost of managing obesity currently costs the nation more than $5 billion a year in healthcare costs, welfare expenditure and lost income taxes.[23] At present, Australia does not have an overarching strategy to tackle obesity.[24]

The rise of chronic diseases in Australia places significant pressure and financial burden on individuals, families, communities, the healthcare workforce and the healthcare system. This is due to the long-term and persistent nature of chronic diseases, as well as their impact on quality of life and overall health, the cost of ongoing healthcare, lost productivity from illness and death, and the limited capacity of healthcare services.[25] Complex disease management, increased healthcare costs and worse health outcomes are associated with being affected by multiple chronic conditions.[15]

Seeking to deliver an effective and coordinated national response to chronic conditions, the Australian Health Ministers' Advisory Council published the National Strategic Framework for Chronic Conditions in 2017.[22] The Australian Chronic Disease Prevention Alliance manages programs and campaigns aimed at preventing chronic disease, and Australia contributes to several global strategies for the prevention and management of chronic disease, which can be found in the Global Action Plan for the Prevention and Control of Non-Communicable Diseases (2013–20).

This global plan aims to develop voluntary targets in disease reduction, including a 25 per cent reduction in premature mortality related to diabetes, cancer, cardiovascular disease and chronic respiratory diseases by 2025.[26] It also aims to reduce premature chronic disease mortality by one third, as part of the United Nations' (UN) Sustainable Development Goals.[25]

ALLERGIES
The rise in allergies

ALLERGIES

Allergies are one of the most common chronic diseases in Australia. Allergies are chronic immune responses to allergens in the environment that are generally considered harmless (such as food, pollen, animal dander and dust mite), or to bites, stings and medications.[27] An allergic reaction occurs when allergy antibodies are produced in the immune system that identify and react with foreign substances.[27]

The prevalence of food allergies has increased in recent decades and is now recognised as a substantial public health burden in developed countries.[28] Lifestyle factors, dietary habits, rising obesity levels, altered food-handling/manufacturing practices, modified exposure to environmental pathogens and maternal-neonatal interactions play a central role in triggering the onset of allergies.[29] Australia has some of the highest allergy rates in the world,[29, 30] and allergies are among the fastest-growing chronic conditions in the country, affecting approximately one in five Australians.[30, 31]

In the last decade, hospital admissions for anaphylaxis have doubled in Australia, and admissions for anaphylaxis due to food allergy in children younger than four have increased five-fold.[27] These trends contribute to an increased demand for healthcare services, an increased cost of care, and a reduced quality of life for those who experience allergies.[32]

2.2. THREATS FROM EMERGING, RE-EMERGING AND PERSISTENT DISEASES

A growing global population, globalisation and the ease of worldwide travel have affected global health and economic stability through the threat and spread of emerging, re-emerging and persistent diseases.[4, 33] Diseases that have been recently recognised or introduced, have newly evolved, or have recently and rapidly changed in incidence or expansion (in terms of geographical, host or vector range) are known as emerging diseases.[34] Examples include the 2019 novel coronavirus (COVID-19), severe acute respiratory syndrome (SARS), Middle Eastern respiratory syndrome (MERS), Ebola, H1N1 pandemic influenza, H5N1 influenza and Zika virus.[4, 5, 35] Re-emerging and persistent diseases are diseases that have historically infected humans and continue to appear and reappear in new locations or in drug-resistant forms after apparent control or elimination.[4, 36] Examples include dengue fever, cholera and drug-resistant tuberculosis.[4]

Emerging, re-emerging and persistent diseases place a significant burden on global economies and public health[37] through their impact on income and the value of lives lost and illnesses suffered.[38] For example, the World Bank has estimated that the gross domestic product (GDP) cost of a severe global flu pandemic is approximately 5 per cent of global income.[5, 39] Surveillance is critical for the early detection, long-term analysis, prevention and control of emerging, re-emerging and persistent diseases.[40] Microbial, human host and anthropogenic factors are the major triggers of these diseases.[4, 34] Infectious diseases are a leading cause of death worldwide.

2.2.1. Infectious diseases

Infectious diseases are caused by microorganisms (including bacteria, viruses, parasites and fungi) that can be spread from one person to another, either directly or indirectly.[41] Transmission can occur through insect bites or the consumption of contaminated water or food, or can be spread from person to person via the transfer of infected bodily fluids.[14, 41] Until the end of the 20th century, infectious diseases were responsible for the largest global burden of premature death and disability.[42] However, thanks to improvements in modern medicine, they have now been overtaken by chronic disease and injury.[43] Although the total burden of infectious diseases in Australia is relatively small (1.6 per cent), they remain a significant cause of illness, and many have the potential to cause serious illness and large outbreaks.[14]

A significant concern in the control of infectious diseases is the development of resistance to antimicrobial agents. This may increase the risk of the longevity of the disease, the treatment requirements, and disease outcomes for the individual.[44] As such, the control of infectious diseases is of utmost importance to the health and wellbeing of individuals and populations worldwide.[45] The World Health Organisation (WHO) reports that changes in infectious disease transmission patterns are likely a major consequence of a warming and unstable climate.[41] Although vaccines are one of the most effective ways to protect people against influenza pandemics, an effective and rapid response to pandemic diseases (the worldwide spread of infectious diseases)[46] can only be achieved through coordinated surveillance, early warning systems, and responses by all levels of government across the world.

COVID-19

In early 2020, the World Health Organisation (WHO) officially categorised the novel coronavirus outbreak (COVID-19) as a global health crisis, and subsequently a pandemic (global outbreak of an infectious disease).

Technology has played, and will continue to play, a critical role in supporting efforts to track, identify and combat this virus; and in keeping connections, business, homes and education functioning while travel and face-to-face meetings are constrained.

IDENTIFYING OUTBREAKS, TRACKING THE DISEASE AND MINIMISING TRANSMISSION

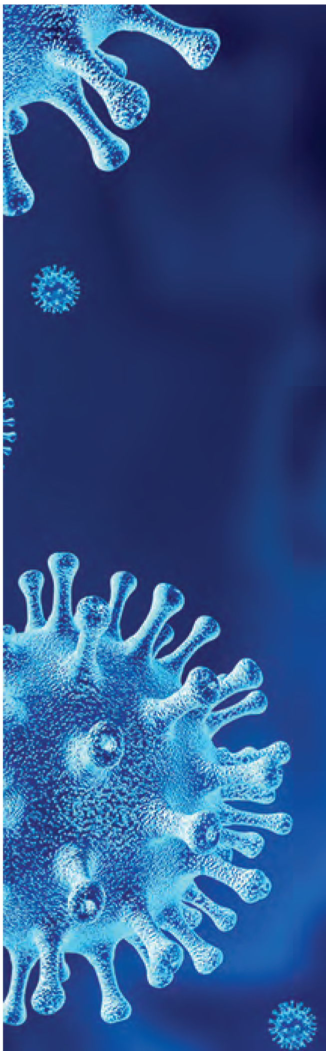
- Using an automated infectious disease surveillance system, an artificial intelligence (AI) epidemiology company sent its first warnings to customers about the new form of coronavirus in December 2019, days before official notices were issued.[47]
- AI and machine learning techniques are also being used in surveillance, and tracking online activity for signs of symptoms. For example HealthMap, a Harvard Medical School-developed AI technology, is being used to monitor COVID-19 cases across the globe in partnership with the World Health Organisation (WHO) and Centres for Disease Control and Prevention. The system updates in real-time as it collects and processes data from the web.
- The Center for Systems Science and Engineering at Johns Hopkins University has created a visualisation of global COVID-19 cases, tracking its progress around the world, including infection, death, and recovery rates.
- In China, drones are being deployed to check peoples' temperatures (using a thermal camera), disseminate announcements to the public (via loudspeakers), and disinfect public spaces (using an autonomous precision spraying tool). Facial recognition-enabled cameras and drones are helping to find people who might be sick or are not wearing masks.
- Robots are being used to disinfect rooms, communicate with isolated people, take vital information, and deliver medications and other goods.

CREATING A VACCINE

- Genomic sequencing technologies and data are playing an important role in building an understanding of the virus. A task force of Chinese researchers were the first to sequence the virus in January 2020, which revealed the pathogen causing the disease.[390]
- A team of scientists from the Peter Doherty Institute for Infection and Immunity in Australia were the first laboratory outside China to grow COVID-19 from a patient sample. This sample has helped to accelerate virus diagnosis and vaccine development.[49]
- Multiple labs around the world are working on producing a vaccine. Some are using machine learning techniques to create new drug candidates or to predict if existing drugs might work as a vaccine for COVID-19.[50,51]
- The University of Queensland (UQ) has created a candidate vaccine for COVID-19 and is working quickly towards pre-clinical testing. The lab's 'molecular clamp' technology can engineer a vaccine that could be more readily recognised by the immune system, triggering a protective immune response.[391]

SUPPORTING BUSINESSES TO FUNCTION

- Video-conferencing, messaging services, and online webinar portals are supporting education, meetings, and conferences. Events can be live-streamed or recorded and made available to thousands of people.
- People are being supported to work remotely using cloud-based software for file sharing, project management and collaboration, among others.
- Smartphone apps, social networking, and other software are helping people to stay connected, take exercise classes and other group activities, and even go on virtual dates.



WHAT MIGHT HAVE BEEN DIFFERENT?

The novel coronavirus outbreak (COVID-19) is an unprecedented global health, economic and human crisis. All over the world, countries are shutting down, trying to keep their health systems from being overwhelmed. Keep your distance. Wash your hands. Stay inside.

What could we have done to ensure our health and economic systems were resilient to a catastrophe of this magnitude? And how might Australia prepare to manage the next pandemic?

We're incredibly fortunate to have one of the best health systems in the world, but it's by no means perfect. As technology evolves and improves, so should the way in which we deliver healthcare – from prevention through to diagnosis and treatment.

The good news is that the gap between the current operation of the health system and its technology-enabled potential creates an enormous opportunity for strong and swift improvement. Closing this gap will set Australia up to not only deal with any future pandemic, but also deeply enhance our capacity to respond to our business-as-usual health care needs.

How would the response to COVID-19 have been different if the pandemic had commenced after all of ATSE's recommendations had been fully implemented? While the pandemic already has seen some of these changes accelerated beyond what we had previously imagined possible (the rapid expansion of telehealth, for example), implementation of these reforms could have facilitated a better response to the pandemic in a number of ways.

In a fully digitised healthcare system, governments and the medical community would have been able to identify and monitor COVID-19 in real time, using machine learning to identify disease outbreaks by looking for spikes in the reporting of relevant symptoms, and scraping the internet for relevant information. This data could be fed into probabilistic modelling and analytical tools to predict and assess pandemic risk, and estimate the potential burden – as well as enable early, and well targeted quarantining measures, and allocation of scarce resources to diagnosis and treatment where it's most needed.

Using telehealth, at-risk people can be diagnosed, treatment plans devised, and appropriate support arranged – all without having to leave their homes. This would also reduce the risk of exposure to COVID-19 for healthcare workers, thus preventing inadvertent spread to other vulnerable patients, and enabling them to save precious personal protective equipment for when it's really needed. We could be using smart devices to automatically monitor patients' temperature or oxygen levels, and prioritise medical care to those who need it most.

If we'd already been geared up with agile manufacturing and supply chains, Australia would have been better placed to support the COVID-19 response with enough critical medical technology equipment when and where it's needed.

Work has already begun in all of these crucial areas – and the COVID-19 pandemic is fast-tracking our response to others. But to be truly ready, resilient, and responsive, we will need to do more and make faster progress. With a new prescription for a healthcare transformation, we can and will create the health system of the future.

2.3. DIGITAL TRANSFORMATION

Increasing personalisation of healthcare, the rising costs of treating chronic diseases, and growing expectations of access to high-quality healthcare are driving the push towards digital and data technologies. Digital technologies are being increasingly applied in the healthcare sector, both within and outside of traditional clinical and diagnostic settings.

Eighty per cent of respondents to an Australian Digital Health Agency (ADHA) survey agreed that digital technology will transform and improve healthcare outcomes for Australians.[53] Four times as many people want to access their personal health information on their smartphone than already do, and want to manage their medications, request refill prescriptions and track aspects of their health using their smartphone.[53] According to MedicalDirector's Patient Engagement Survey 2018, Australians want doctors to adopt technology solutions to improve convenience, patient empowerment, healthcare outcomes and communication regarding their health.[54] However, the rise of electronic health records (EHRs) also means that a digital divide is affecting doctor-patient relationships; physicians have less eye contact with the patient while they record patient data, resulting in a less personal experience, frustrating both doctors and patients.[55]

The collection of high-quality, structured health data is a priority for Australia's healthcare sector over the next decade, as digital technologies become increasingly interconnected and communicative. Standardised, interoperable health data must be made available for the research and development (R&D) of new diagnostic clinical support technologies, particularly AI-driven platforms such as diagnostic software based on machine learning, and natural language processing for capturing clinical notes.

2.3.1. Interoperability, integration and data sharing

The biggest challenge in digitising healthcare and enabling the future collection and application of health data and analytics is the lack of interoperability within Australia's siloed healthcare systems. In Australia, state and territory health organisations operate using disconnected systems that cannot communicate with one another. Individual healthcare services use unique information technology (IT) systems, and patients often cannot access their own health information. Hospitals and public health facilities also have fragmented, inflexible healthcare systems and dated infrastructure, which means that an overwhelming majority of patient information is not shareable.[23] Ineffective information exchange contributes to poor-quality data and disjointed care. For example, an estimated 14 per cent of pathology tests are ordered due to a lack of access to patient history.[53]

Improving the interoperability of data and systems within Australia's healthcare sector is identified as a strategic priority in Australia's National Digital Health Strategy.[53] This will require a step change from analogue, paper-based communication systems to digital systems that can capture, store and communicate patient data securely between patients and healthcare professionals, as well as between organisations. This, in turn, will require the standardisation of data collection, nomenclature and systems.

Continuous data exchange between medical technology systems and software solutions, along with the ability to analyse large volumes of data, will be crucial in making the shift from episodic to continuous patient care.[56] However, current interoperability initiatives are undermined by outdated EHR systems; a lack of standardisation in health IT; and information blocking, an act that interferes with, prevents or discourages the access, exchange or use of electronic health information.[56]

2.3.2. Cybersecurity

Storing patient data in a central system and standardised format can allow controlled or regulated access to patient files, but it also increases the risk of a data breach. Hospital IT systems are increasingly vulnerable to malicious software, such as ransomware, which could lead to the loss of patient records and disruption to booking and management systems.[57] A cybersecurity breach could result in unauthorised access, deletion or theft of health information.[58] Data privacy and the security of new digital systems are critical considerations in the transition to digital health.

> The ADHA has established the Digital Health Cyber Security Centre to protect national digital healthcare systems and sensitive health information from cyberthreats. The centre shares best-practice guides and mitigation strategies to improve information security and risk management across Australia's healthcare system.[53]

2.4. INCREASING CONSUMER EXPECTATIONS

The patient journey through the healthcare system is increasingly affected by consumer expectations. Through technology, consumers are experiencing highly personalised interactions in other aspects of their work and lives, such as education, shopping and media,[54] and are beginning to have similar expectations of their healthcare.

Person-centred care (or personalisation of healthcare) implies that the individual has choices and control over the way in which their care is planned and delivered.[59] This represents a new relationship between people, healthcare professionals and the healthcare system.[60] Although a consumer-focused, integrated healthcare system is identified as one of the strategic outcomes of the National Primary Health Care Strategic Framework,[61] a recent report by the Productivity Commission highlighted a lack of patient-centred care in Australia.[62]

2.4.1. Meeting and addressing patient expectations

Consumers are now far more informed and are increasingly reliant on the internet to find medical and health information. Consumers are also increasingly frustrated by a lack of choice and transparency in Australia's healthcare system. In particular, there are growing expectations that outcome and performance data should be publicly available.

Consumers also have higher expectations of what constitutes best-practice healthcare and want better health outcomes. This is increasing demand for proactive health and wellness solutions, which — when combined with new technologies – is changing the way in which healthcare services are delivered. Consumers expect governments, healthcare services and healthcare professionals to help them to become more informed and involved; manage their health where possible; and provide prompt, appropriate and individualised help when required.[63] They expect to engage and share their information with hospitals and healthcare professionals, who will use this information to further personalise patient experiences.

A shared decision-making process allows clinicians and individuals to work together to gain understanding of their health and make healthcare decisions based on a patient's circumstances.[62] However, determining the extent of a patient's involvement can be challenging; each patient is unique, and their readiness to participate in the decision-making process is influenced by many factors, including the type of health issue they are dealing with, their level of education and their age.[64] For some consumers, personalisation may mean empowering them to make healthcare decisions; for others, it may mean asking a healthcare professional to make the decision for them.

2.4.2. Improved quality, safety and coordinated care

Australia's healthcare systems generally deliver high-quality care and good patient outcomes. However, we still have fragmented service delivery, a lack of coordination across health silos, and an insufficient patient focus.[7] For example, 65 per cent of people surveyed for the National Digital Health Strategy reported that the Australian healthcare system is difficult to navigate.[53] Without integration, there will be increasing gaps in care, conflicting advice or treatments, and duplication and wasting of resources. Consequently, patients will experience difficulties in accessing appropriate and targeted care when navigating between services.[7]

Healthcare providers also report challenges. In a survey of healthcare providers 61 per cent said that central systems and processes for patient lifecycle management are ineffective.[65] Fifty-eight per cent of respondents felt that hospital-to-patient communication mechanisms were inefficient, and 54 per cent reported that they encounter limited capabilities to gain meaningful insights from patient data in relation to patient service.[65]

Patient confidence in demanding personalised and affordable healthcare services is a push factor for delivering value-based healthcare in Australia. In order for healthcare professionals to increase their efficiency and improve their delivery of care, new patient-centric healthcare model strategies are recommended to ensure the continued viability of their organisations.[66]

Additionally, technology can be used to remove silos between healthcare providers and expand the geographic reach of healthcare services. A shift from 'volume' to 'value' is required, with healthcare professionals using technology to develop personalised treatment and provide a better healthcare experience.[67]

CLIMATE CHANGE

Climate change is a growing threat to human health

CLIMATE CHANGE

Climate change is considered to be one of the greatest global threats to health in the 21st century.[68] Climate change affects health in many ways, either directly through extreme events (such as heatwaves, floods or bushfires) or indirectly (for example, through worsening air quality and effects on mental health). Most common infectious diseases, including those transmitted by insects, are highly sensitive to climate variation.[69]

Children, older people, those with pre-existing medical conditions, pregnant women, people living in rural and remote areas, Aboriginal and Torres Strait Islander peoples, and people with chronic occupational exposure to high temperatures and air pollution are at increased risk from extreme events.[70] In Australia, wildfires and heatwaves are currently responsible for approximately 60 per cent of all direct fatalities related to natural hazards.[70]

According to a global study conducted in 2011, an increase in the hazardous components of bushfire, such as PM2.5 (fine particulate matter with a diameter of 2.5 micrometres or less), was estimated to induce an increase of at least 5.6 per cent in daily, all-cause mortality; 4.5 per cent in cardiovascular mortality; and 6.1 per cent in respiratory mortality.[71]

In 2019, the Australian Medical Association (AMA) reported significant linear associations between exposure to higher temperatures and greater mortality in the Australian cities of Sydney, Melbourne and Brisbane.

Furthermore, there is an estimated annual productivity loss from heat stress of $616 per employed person in Australia. Doctors for the Environment Australia (DEA) reports that heatwaves have caused more deaths in Australia over the past 100 years than any other natural event.[68]

CHAPTER 3

Enabling technologies

CHAPTER 3

Enabling technologies

Technological advancements have the potential to transform Australia's healthcare system. Digital and data technologies will generate complex data for research, the application of smart digital technologies will inform and assist patients and healthcare professionals, and advanced biotechnologies will bring us closer to precision medicine.

This chapter provides an overview of existing and enabling technologies that have the potential to address challenges in the healthcare sector and support the shift in focus to prevention and wellness. It also examines how these technologies support or enable the potential technology solutions identified by ATSE.

TABLE 2
Key groups of enabling health technologies

INFORMATION TECHNOLOGY	SMART DIGITAL TECHNOLOGIES	ADVANCED BIOTECHNOLOGIES
Digital health records Artificial intelligence Data analytics	Telehealth Networked medical devices Mobile health apps	Omics technologies Gene & cell therapies Bioprinting Combination of drug & devices

3.1. INFORMATION TECHNOLOGY

Information is the currency of health, from patient data captured at the point of care through to secondary data used for reporting, research and the development of clinical guidelines.[72] The use of digital technologies in the healthcare sector is growing and changing rapidly.[14] However, the sector is also recognised as one of the last to be disrupted by digital technologies, despite being the sector with the most to gain.[73]

Over the past two decades (2000–19), e-Health was the umbrella term for telehealth, which involves the electronic transmission, storing and retrieving of digital data for clinical, education and administrative purposes, both locally and remotely. Digital health is the next stage in the evolution of information and communications technology (ICT) in health, leading to consumer driven changes in their own health and wellbeing.[74] Additionally, digital health is the electronic management of health and health-related information, allowing connections between various points of care so that information can be shared securely.[75, 76]

Digital health and enabling technologies that are contributing to big data in healthcare include health informatics, mHealth, telehealth, artificial intelligence and devices supported by the Internet of Medical Things (IoMT) (Figure 3). The integration of digital technologies into all levels of healthcare and research will enhance our understanding of health, diseases, and the ways in which doctors and hospitals work with consumers. The use of these technologies can yield better health outcomes for patients and improve care delivery and workflow for healthcare providers. For example, increasing the uptake and integration of digital health technologies will allow more accurate diagnosis and prescription, increased automation, a reduced patient burden for hospitals, and increased monitoring of patients' journeys through the healthcare system.

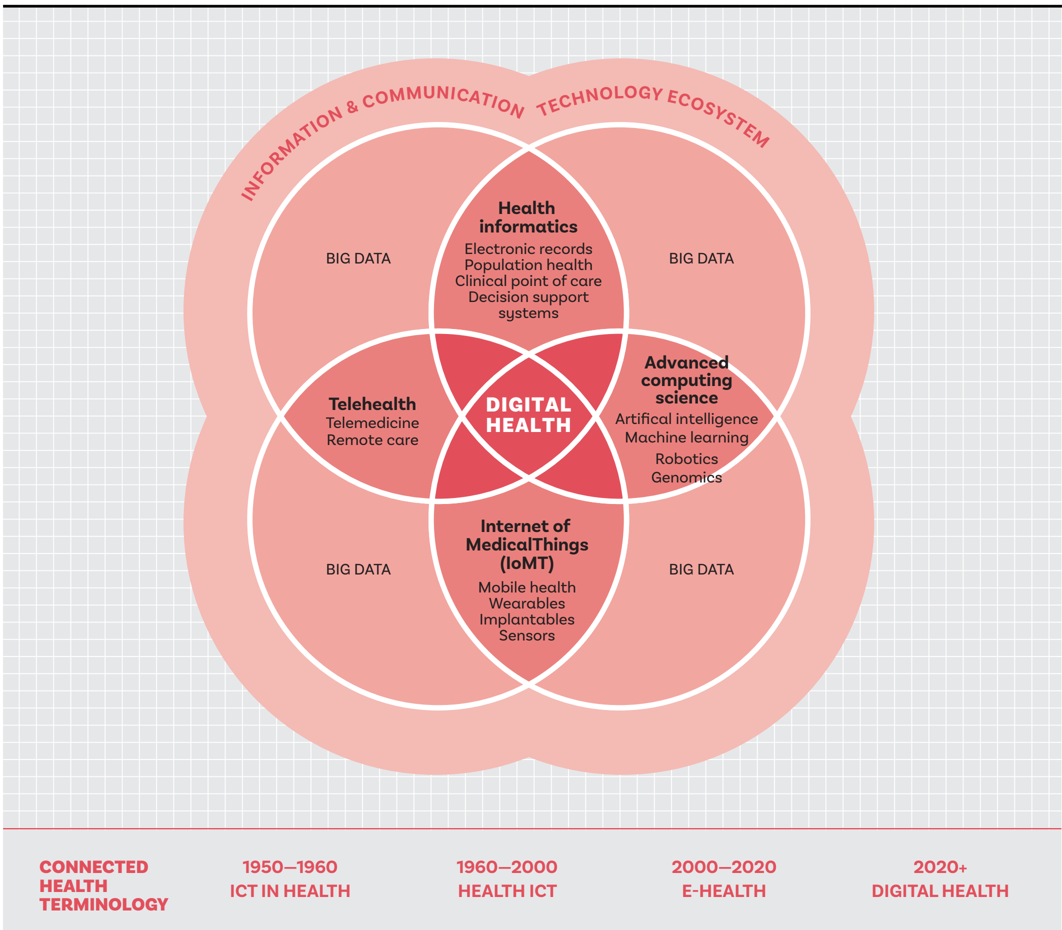


FIGURE 3

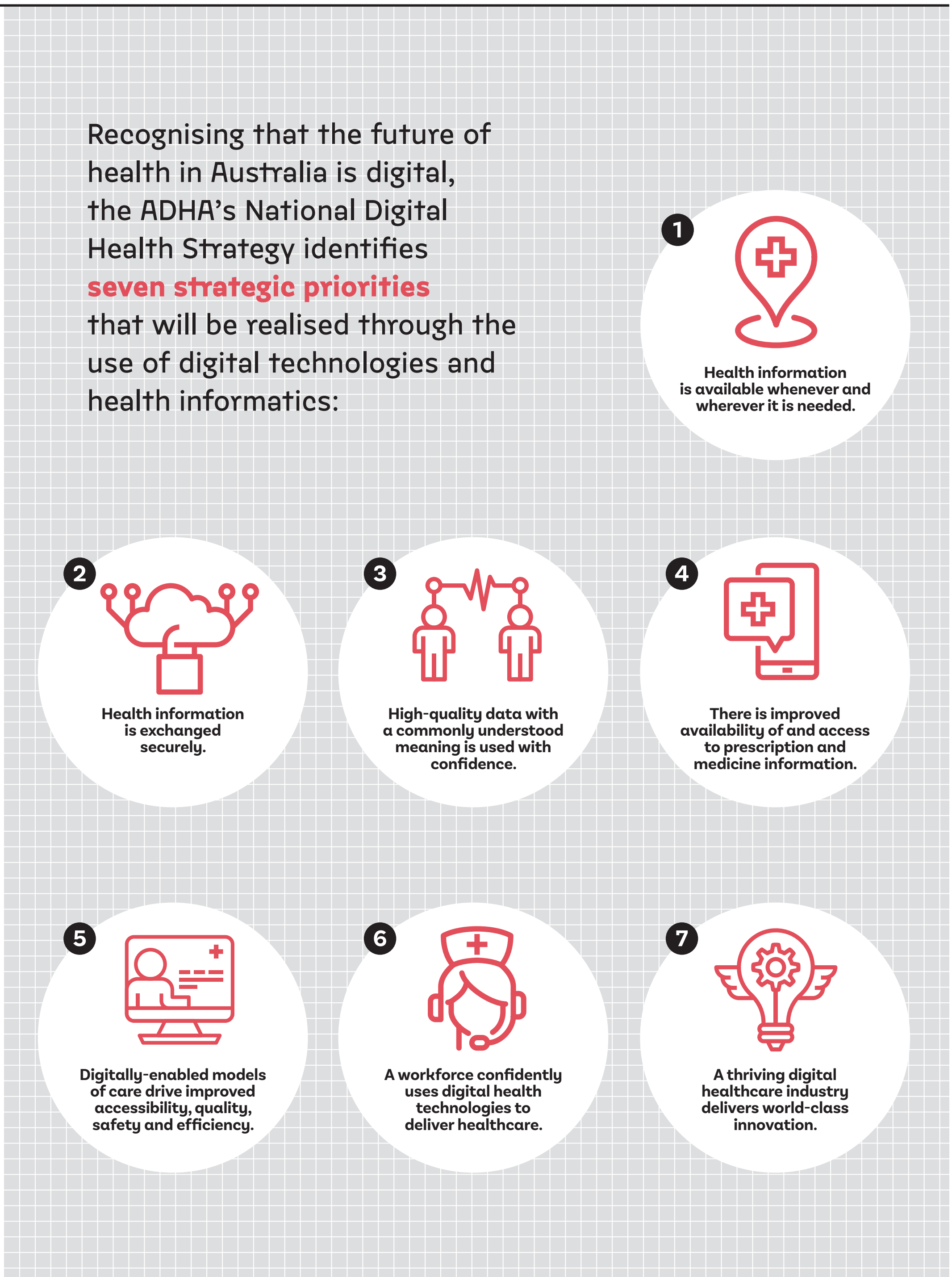
A summary of digital health in the context of other technology-enabled care, supported by the IoMT

3.1.1. Digital health records

Patient health records, also known as digital health records, are electronic summaries of a patient's key health information. These records can vary depending on their transparency, clinical purpose, and how patient data is managed and accessed.

PRIORITIES

Seven strategic priorities of the ADHA's National Health Strategy[53]



There are three types of digital health record:

1. Electronic medical records (EMRs)
2. Electronic health records (EHRs)
3. Personal health records (PHRs)

These are summarised in Table 3. The distinction between EHRs and PHRs is diminishing as consumer portals emerge as a convenient way to view or present information for consumers.[77]

TABLE 3 Differences in digital patient health records[77,78]

ELECTRONIC MEDICAL RECORDS (EMRs)	ELECTRONIC HEALTH RECORD (EHRs)	PERSONAL HEALTH RECORD (PHRs)
Created and resides within individual healthcare organisations Data is collected by health practitioners as digital versions of paper charts Can be managed, added to and accessed across multiple healthcare organisations	Can be managed, added to and accessed across multiple healthcare organisations Data from all practitioners involved in a patient's care	Similar to EHRs, but health information is accessed, managed and shared by individuals Data includes information from clinicians, home monitoring devices and patients

For EHRs and PHRs to work effectively, the sector needs to shift from a server-based environment to a cloud computing-based environment. Computing capabilities are essential components of a cloud model, including server time, storage, processing, memory and network bandwidth.

APPLICATIONS

Most healthcare organisations are already using digital health records. To further facilitate the use of these technologies, it will be important to digitally collect, store, collate and retrieve clinical information, including clinical notes, images and paper-based notes. Clinical health informatics and machine learning techniques will empower digital health records to analyse available healthcare data and provide decision-making support to healthcare professionals.

Interoperable healthcare systems will also facilitate the sharing of patient data between healthcare professionals during patient treatment, recovery and post-operative follow-up. Patients with chronic diseases can benefit from such systems as they often have more than one consulting healthcare professional. Capturing related data on the treatment and management of chronic diseases and their impact on primary care, quality of life and employment will support the development of strategies aimed at preventing and managing chronic disease. Enabling data access across healthcare organisations is equally important for monitoring and improving the personalisation of healthcare. The collection of disease data and reporting will also support public health surveillance for infectious diseases.

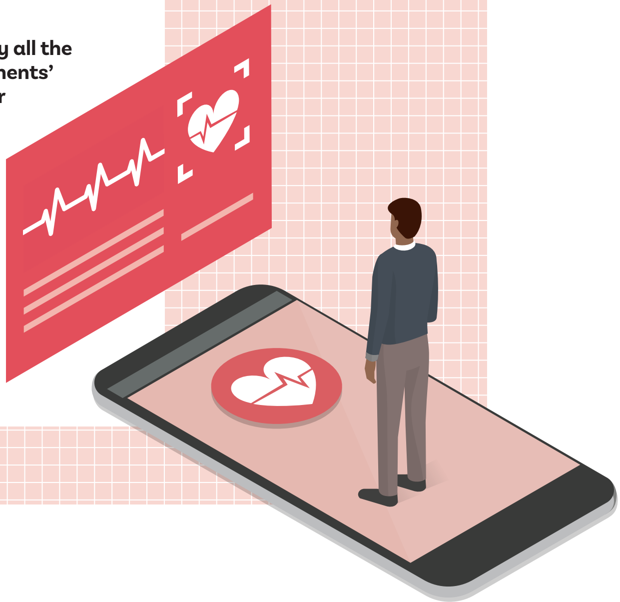
MY HEALTH RECORD

My Health Record (MHR) is a centralised personal health digital record platform used by individuals and healthcare organisations to upload or view patient information.[77] It provides a secure online summary of a patient's health information, including prescriptions, medical history, known health conditions and treatments.

MHR gives consumers access to important health information; this information is also available to treating clinicians when needed, including in an emergency.[79] Healthcare providers can use MHR to access patient information, reducing system inefficiencies, improving the quality of consultations, and minimising clinical errors due to a lack of medical history. Patients can access their health information securely online or through a mobile app, giving them a greater role in planning their care. They can also manage and control what information is captured by MHR and who is allowed to access it – such as doctors, hospitals and other healthcare providers.[80] The MHR system is designed so that individuals can opt in or out of having a record. This requires individuals to assess the risks and benefits of MHR based on their individual context.

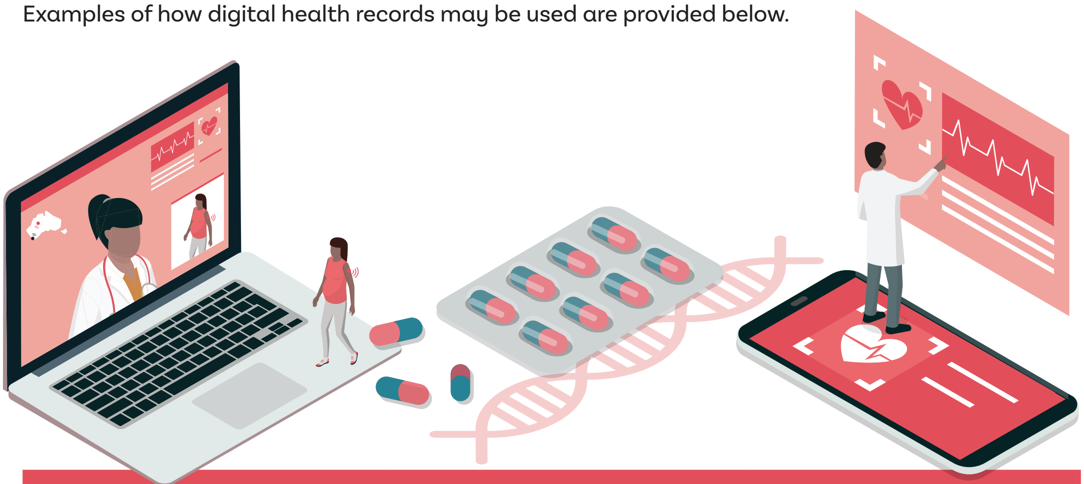
The MHR system is managed by the ADHA and operates under the My Health Records Act 2012 and the Healthcare Identifiers Act 2010.[81] These acts establish roles and obligations for key participants such as healthcare providers, the system operator and individual healthcare recipients. In particular, the legislation governs the registration framework for individuals and entities such as healthcare provider organisations to participate in the MHR system, and provides a privacy framework (aligned with the Privacy Act 1988) specifying which entities can collect, use and disclose certain information in the system (such as health information contained in a healthcare recipient's MHR). It also details the penalties that can be imposed for the improper collection, use and disclosure of this information.

The National Digital Health Strategy was approved by all the Health Ministers on the Council of Australian Governments' (COAG) Health Council and identifies priority areas for reform to deliver by 2022.[82] For MHR specifically, these include an expansion program, an innovation platform, improvement of medical device information, and the implementation of a framework to enable safe and secure use of MHR system data. If statutory, privacy and security requirements are met, the availability of population-wide, de-identified health data enabled by MHR offers an invaluable opportunity to verify what works in the healthcare system (for example, medication results and healthcare provider performance).[79]



PLATFORMS

Examples of how digital health records may be used are provided below.



DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
It is envisaged that digital health records will be networked, interconnected and interoperable. Technologies for data collection, storage and management will interact through the use of national patient portals, such as My Health Record, and patients will have better access to their own health data.	Precision medicine and technologies, such as genomics, will have significant computational power. Digital health records will be used to collect and assimilate clinical data for training and analysis.	Coordinated care teams will use digital health records to communicate, share patient data and make referrals across different healthcare providers. Digital health records will facilitate communication through increased interoperability, data sharing and the assimilation of paper-based or mixed-media patient information.

BARRIERS AND CHALLENGES

Challenges associated with the deployment of digital and data records in Australia include interoperability and data challenges, cybersecurity and data privacy challenges, network infrastructure challenges, and skill shortages.

Interoperability and data In a white paper by HISA (Health Informatics Society of Australia), Australia's healthcare system is 'data-rich, but information poor'.[83] One of the main challenges is the growing demand for clinical information to be shared between individual healthcare professionals, healthcare provider organisations and state/territory health departments.[84] Information silos persist between institutions and healthcare services, limiting the availability of clinical data and EHRs for research and operational purposes. Further challenges include capturing and recording health information (in the correct format, and with consistent terminology), and ensuring secure communication between healthcare professionals.[85]

Cybersecurity and data privacy The rise in domestic and international cybersecurity threats has increased the need for strong cybersecurity processes in Australia. Many organisations still have inadequate cybersecurity protocols, and data privacy is now a major concern for many Australians. It will be important for medical devices to run on supported, secure operating systems.[86]

Network infrastructure The widespread adoption of digital health records in healthcare is dependant on the availability of network access. Australia's National Broadband Network (NBN) is primarily a fixed-line connection that relies on extensive fibre and copper lines to connect consumers to the internet. There are concerns about the availability of NBN connections in regional areas, leaving non-metropolitan residents with unequal network access or poorer internet speeds. The fifth-generation (5G) mobile network is in the process of being rolled out nationally and may improve network access in regional areas. The challenge for Australia is to improve the bandwidth and coverage of broadband and mobile services in regional and rural Australia so that these communities can equitably benefit from all forms of digital health. This requires adequate data limits, affordable equipment, and digital ability and literacy.[87]

Shortage of skills As Australia's healthcare sector responds to the digital revolution and redesigns clinical care, there will be a significant need for a professional workforce with skills in digital health literacy, clinical informatics and change leadership. Workforce planning approaches will have to address the need for interdisciplinary and multidisciplinary specialists with informatics skills, machine learning skills and clinical care knowledge.

> The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) – and agencies around the world, such as the WHO – agree that telecommunication technologies, such as 5G, do not cause adverse health impacts. All telecommunications, including new 5G technology, must comply with the exposure limits detailed in the ARPANSA Standard and the Australian Communications and Media Authority's regulatory framework.

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

In the future, digital health approaches and informatics-driven systems will improve patient outcomes, workforce capability and efficiency, and R&D capacity. Health information systems will be able to share and use patient information and medical records. The National Digital Health Strategy includes a number of priority actions to support this vision, including digital health records, and systems for decision-support and population health surveillance.

Digital health records By 2022, the ADHA wants all healthcare providers to be able to contribute to and use health information in My Health Record on behalf of their patients to access digital health records at any time, unless the patient chooses not to participate.[89] To date, take-up has been comprehensive among GPs, pharmacies and public hospitals (around 90 per cent registered) but lower among private hospitals (33 per cent) and pathology and diagnostic services (43 per cent). Evidence provided to Senate Estimates by the ADHA indicates that uptake has been slow among aged care, allied health and specialist facilities.[90] The ADHA is continuing to work with all providers and clinical groups (such as software providers and specialists) to increase registration in low-use sectors. Limited take-up in aged care is due in part to the sector's lower levels of digital maturity, and is also affected by uncertainty until the outcome of the Royal Commission on Aged Care is known.

Decision-support systems Healthcare professionals will be able to make more informed decisions using clinical decision-support systems with access to EHRs and patient information. It is predicted that EHRs will eventually be surpassed as clinical decision-support systems become the user interface of choice.[91]

Population health surveillance systems Digital health surveillance facilitates the global monitoring of populations and security threats, as well as local health risks.[92] With the use of machine learning (discussed in the next section), disease outbreaks can be identified in real time by looking for spikes in the reporting of relevant symptoms.[93]

3.1.2. Artificial intelligence and data analytics

The Commonwealth Scientific and Industrial Research Organisation's (CSIRO) Data61 defines Artificial Intelligence (AI) as a collection of interrelated technologies used to solve problems autonomously and perform tasks to achieve defined objectives without explicit guidance from a human being.[101] This involves the development of 'smart' machines that mimic human intelligence or cognitive function and are capable of learning from data. AI encompasses a host of technologies, including machine learning, and has applications in a broad range of areas such

BLOCKCHAIN

Blockchain is gaining traction as an emerging form of healthcare security technology. It is a decentralised, distributed, digital public ledger that stores verified transactions in an encrypted chronical chain, resulting in permanent data storage. It allows patients to assign access rules to their medical data[94] and will help to maintain the privacy and integrity of personal patient data by restricting access to a patient's medical record and treatment history.

Blockchain technology is expected to improve medical record management, insurance claim processes, and clinical and biomedical research.[94] A successful trial of blockchain technology has been undertaken, but greater evidence of blockchain's efficacy is required prior to widespread implementation.[94-96]

Blockchain can function as a useful component of the data security landscape, in combination with other security technologies.[97,98] Examples of other security technologies include the following.

- **Next-generation firewalls (NGFWs). These create IT security structures that allow greater amounts of data to be stored. NGFWs perform the same basic function as legacy firewalls but offer malware-blocking features.**
- **Healthcare cloud-based securities. These are used to secure data that is stored, maintained and backed up online and preferably onshore. The Australian Cyber Security Centre (ACSC) is the Australian Government's lead agency on national cybersecurity and is part of the Australian Signals Directorate (ASD).**
- **Secure direct messaging and health information exchange (HIE). This enables streamlined, paperless, secure and interoperable connectivity between clinical systems, allowing healthcare providers to exchange patient information with other members of a patient's care team.[99] By 2022, the ADHA aims to use this mechanism to end the dependence on paper-based correspondence, including fax machines and post.[100]**
- **Biometric security applications. These build a unique profile of an individual from scans of their physical features (for example, fingerprints), linking that profile to their personal medical history. These applications use infrared light technology and high-quality cameras to create data points. Development of this technology includes biometric authentication applications.**

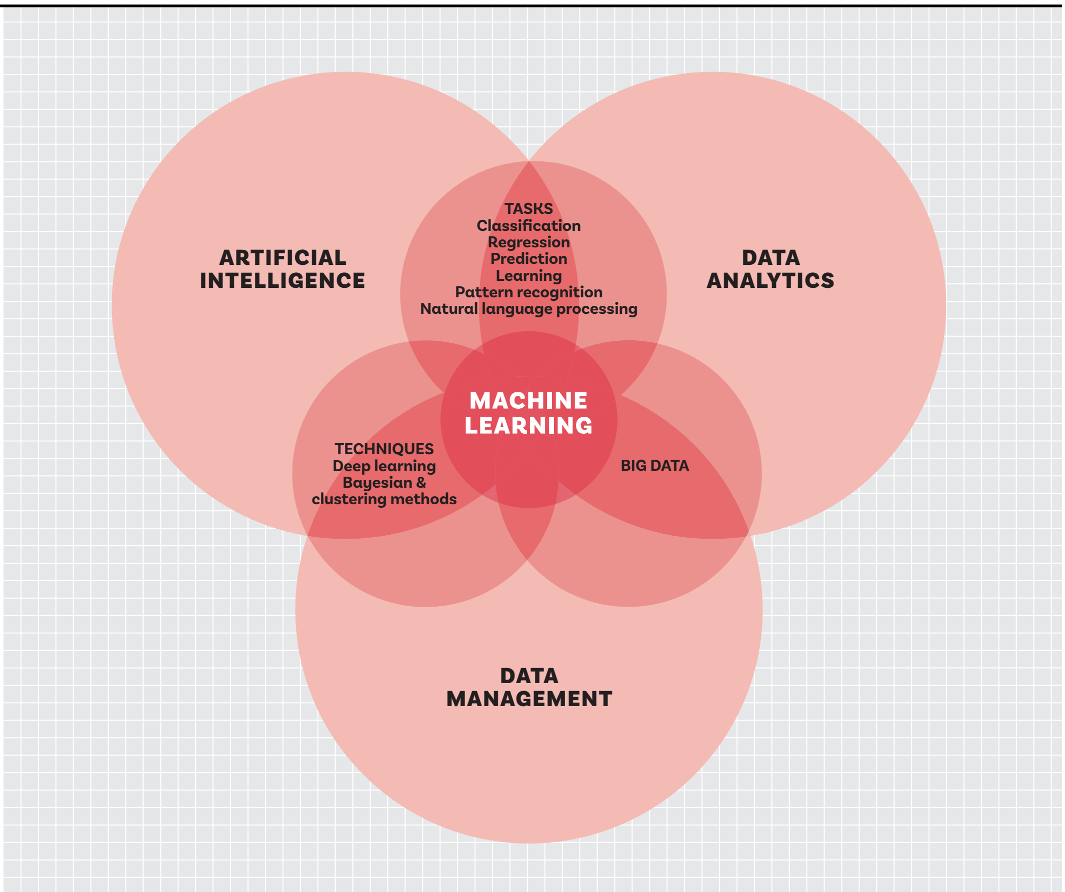
as tax assessment, predictive agriculture and healthcare diagnostics. Data analytics is the science of analysing raw data to uncover useful insights. Organisations use it to help improve business operations, efficiency and productivity; and researchers use it to verify or disprove scientific models and theories. Data analytics applies machine learning and uses several data sets to look for meaningful correlations.

Machine learning is a subset of AI and data analytics. It has been defined as a computer's ability to perform tasks without being given explicit instructions, instead learning how to perform those tasks by finding patterns and making inferences.[102] Machine learning trains algorithms to learn from historical data to complete a specific task; once trained, these algorithms can be applied to new data, and this process can be repeated and refined until optimal performance is achieved. For example, a tumour can be identified using previous images and notes related to tumour cases. Regression is another useful machine learning task. It can be used to determine a patient's glucose levels, and can be developed to carry out predictions, diagnosis and recommendations.

Data management is essential to support machine learning (Figure 4), and systems need to include processes for retrieving, storing, securing, maintaining, generating and ethically managing information. Health information is primarily acquired through medical records, discharge summaries, medical images and clinical notes. However, the increasing digitisation of healthcare has seen significant growth in the volume of health data – a valuable resource for research and development of data-driven health technologies.[103]

Australia is actively contributing to the international discussion around AI systems, with several key bodies (including CSIRO and the Office of the Victorian Information Commissioner) investigating legal, social and technical issues surrounding the technology. In 2019, the Australian Council of Learned Academies (ACOLA) produced an important report on AI, which included a discussion of the application of AI in health and aged care;[104] and the Federal Government recently funded the development of a national AI ethics framework aimed at steering the design and application of AI technology to align with ethical and inclusive values.[101] The Australian Government also committed $25 million in additional funding in the 2018–19 budget for the Cooperative Research Centres Program (CRC-P) for projects with a focus on AI. The AI industry is likely to become a highly profitable industry for Australian and international markets. Predictions forecast that AI will contribute to the global economic activity of up to US$13 trillion by 2030, or a 16 per cent increase in cumulative GDP.[105]

FIGURE 4
Artificial intelligence and data analytics are driven by machine learning and data management



APPLICATIONS

As Australia's population grows, the healthcare system is expected to produce a significant amount of health data, which may be available for use by machine learning technologies to facilitate better health outcomes for patients.

AI has the potential to become a useful clinical tool for the diagnosis and treatment of patients, using machine learning algorithms that detect disease markers, improve medical imaging applications or perform genomic analyses. It can also be used as a tool to support clinical decision-making, assimilating unstructured clinical notes and managing data to improve ease of access, research efforts, and patient transport and hospital logistics.[108] For example, AI and data analytics will be able to improve treatment personalisation and tailoring, and to support the use, management and sharing of patient data to deliver a patient-centred approach to care.

The integration of supportive AI technologies in aged care may also improve patient recovery and rehabilitation among Australia's older population. In addition, AI technologies may help to streamline tedious or error-prone aspects of medical diagnosis and treatment, and are likely to become integrated into primary healthcare through tools used by healthcare professionals in point-of-care diagnostics (for instance, tools to detect diabetic eye disease in hospital patients).[109] AI may also become integrated into the healthcare system through digital applications that end-users engage with at home – for example, diagnostic applications for imaging skin cancers, which individuals can use to monitor their own health conditions remotely.[110]

At the population level, health data and machine learning tools can be used to map emerging infectious disease and trends in chronic and lifestyle diseases, and to predict future threats arising from climate change. By filtering and compiling this information, AI can supplement healthcare professionals' efforts to make decisions in rapidly changing situations. For example, using digital and data technologies to detect and monitor disease trends within the population can facilitate early intervention and preventative care and reduce the economic burden of disease. (While machine learning techniques are more likely to be consistent and objective than humans, it is important to note that they will not be free from bias.)

THE FOUR V'S OF BIG DATA AND DATA FORMATS

BIG DATA

Extremely large data sets — from various sources of information — result in big data. Big data technologies are those that generate, collect, analyse and communicate data. The four Vs of big data in healthcare are volume, velocity, variety and veracity.

- **Volume of data refers to the amount of health data that is created and accumulated over time.**
- **Data velocity refers to the rate at which real-time data is retrieved, analysed and compared for use in decision-making (for example, to monitor or detect health conditions or infections).**
- **Data variety refers to the different formats in which data is available.**
- **Data veracity refers to the reliability of data being credible and free from errors.**

Achieving the four Vs requires advances in platforms and tools to accelerate big data analytics.[106]

When collecting, managing or using health data, six additional factors must also be taken into account:[107] validity (data accuracy), viability (data relevancy), volatility (how often the data varies), vulnerability (data security), visualisation (data presentation) and value.

Data can be collected in a number of formats, including:

- **Structured data, which is defined and easily managed by a machine**
- **Unstructured data, which includes audio, video and social media**
- **Semi-structured data, which includes emails or documents**

Structured data can be easily analysed and manipulated by machine learning technologies, but unstructured data is the most common form of data at present.

The challenges facing big data and data management platforms include availability, ease of use, the ability to handle (combine and convert) different data streams, and to manipulate data at different levels of granularity, ethics, privacy and security.[106]

AI has also facilitated the development of a range of assistive technologies, particularly in the area of robotics. Surgical robots and assistive patient care robots are two common, AI-based technologies that are already used in hospitals to improve patient health outcomes and welfare. Patient assistive robotic technologies are robots designed to assist patients and nurses by providing care support in hospitals, nursing homes and individual households to people with disabilities, older people and people with illnesses.[111] Combining AI and robotics, social robots may provide social interaction, medical support and physical assistance to patients in rehabilitation, people with disabilities, people with chronic illnesses and older people to improve independence. These robots may reduce hospitalisation rates by improving patient motility and performing routine tasks (for example, checking vital signs and improving medication compliance).

Machine learning technologies are already being used to improve early diagnosis of disease and treatment plans for patients suffering from cancer and chronic disease. For example, machine learning technologies can use medical records, patient data and best-practice data to determine the best treatment options for patients, which can result in reduced mortality rates and improved health outcomes for the Australian population as we move towards a preventative healthcare system. Further medical machine learning applications will improve quality of life and wellbeing by promoting healthy behaviour, and by identifying populations who are at risk (Table 4).

TABLE 4
Major applications of machine learning in healthcare

APPLICATION	EXAMPLE
Automation	Home automation systems or 'smart homes' are automation systems for controlling things like lighting and indoor climate. These systems can promote health and wellbeing among people with disabilities and older people by allowing them to stay in their homes for longer.[116]
Clinical trial research	Electronic phenotyping and monitoring medication adherence data can optimise patient selection for clinical trials.[117, 118]
Decision-support tools	This type of machine learning algorithm can be trained on large primary healthcare datasets and used to assist healthcare professionals with decision-making.
Disease identification/ diagnosis	Advanced imaging data can be used to detect breast cancer.[119]
Disease mapping and outbreak prediction	Infectious disease transmission can be mapped for public health and biosecurity purposes.[120]
Drug discovery	Drug molecule screening and computational vaccine development can be automated.[121, 122]
Smart EHRs	Natural language processing can be used for data extraction and the assimilation of clinical notes.[123]
Sleep-assisting technologies	Technology for sleep management can help individuals to measure the quality of their sleep, and to manage their sleeping environment and activity to improve wellbeing.[124]
Precision medicine	Personalised treatment and monitoring technologies can be used for cancer or stroke patients.[125, 126]
Preventative care	Early preventative intervention tools can use a patient's personal data to catch type 1 diabetes, discover indicators for Alzheimer's, predict breast cancer and cardiovascular disease, etc.[127]

Surgical robots are already used in Australian hospitals. The original surgical robot (the da Vinci Surgical System) has been used for the past 13 years for a range of procedures.[112] In 2020, Victoria will host Australia's first academy to train surgeons in robotics techniques. The Australian Medical Robotics Academy will prepare the next generation of surgeons to perform cutting-edge procedures using medical robotics.[113]

The first assistive robot used in Australia was Pepper, a humanoid robot trialled in 2018 at Townsville Hospital in Queensland. Pepper was designed to provide patients with information about the hospital and to serve as a patient concierge.[114]

PLATFORMS

Examples of how AI and machine learning technologies may be used are provided below.

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
AI analysis of big data will be used for the tracking, surveillance and scrutiny of population health, vastly increasing our ability to monitor trends in population-level health and wellbeing. Decision-support technologies based on AI and machine learning will reduce clinical workload and offer significant practical benefits to healthcare professionals, as well as increasing patient engagement. Machine learning technologies will improve risk prediction and streamline services to allow faster access to patient data.	Deep learning in genomics will be used to identify genetic mutations and disease links in large health datasets, and to identify novel biomarkers of disease and individualised drug targets.[128]	Many AI technologies will function as digital tools that are accessible across multiple healthcare providers and potentially by patients themselves. By incorporating diverse clinical data (for example, clinical notes, imaging data and discharge summaries from all healthcare providers), AI can be used to track a patient's journey through the healthcare system for the purposes of improved health management. The development of machine technologies will promote collaboration between hospitals, GPs and allied health professionals to provide clinical data for algorithm training.

BARRIERS AND CHALLENGES

There are numerous challenges in developing and adopting AI.[115] Due to the scope and depth of potential AI applications, these challenges have been classified into seven different categories, listed in Table 5.

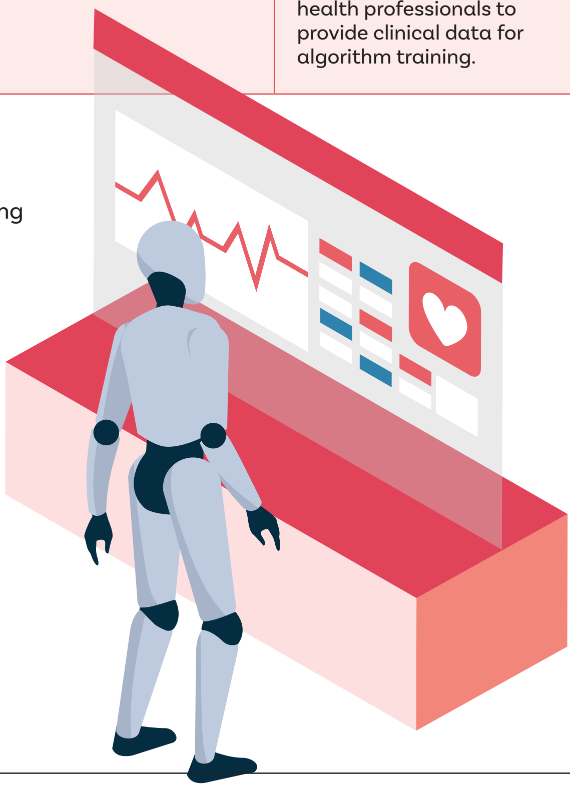


TABLE 5
Examples of challenges in AI development and implementation

AI CHALLENGE	SUMMARY
Data	• Quality and quantity of input data[129] • Transparency and reproducibility • Lack of data integration, continuity and collection standards • Time required to sort, acquire and annotate data[130]
Economic	• High computational costs, increased treatment costs to patients and hospitals
Ethical	• Responsibility for, and explanation of, decision-making is not visible to the user or another interested person i.e. 'black-box' issue[101] • AI discrimination and moral dilemmas • Machine versus human judgement • Implicit bias
Political/legal	• Copyright and privacy issues • Assigning responsibility and accountability[131] • National security threats from international data sharing • Re-identification of patients from de-identified data[132]
Social	• Patient and clinician readiness • Equity of access, social and cultural barriers, and human rights[129] • Country-specific disease profiles and medical practices • Unrealistic expectations of AI
Technological	• Lack of transparency and interpretability • Handling big data and unstructured data • Design of AI systems • Diagnostic tasks not having just one answer • Availability of digital infrastructures, data centres and structured data-sharing systems[104]
Workforce	• Dramatic changes in the capabilities of the workforce[101]. For example, a recent study by Google Australia and consulting firm AlphaBeta found that Australian workers will need to increase the amount of time spent on learning new skills by 33 per cent in their lifetime, and that job-related tasks will change by 18 per cent each decade.[133]

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

Over the next ten years, AI will evolve beyond simple algorithms designed for one task to become complex, interoperable platform technologies. Adoption rates are likely to increase in a range of sectors as AI becomes a tool for reducing workload and promoting growth, with research suggesting that 70 per cent of businesses will have adopted some form of AI technology by 2030.[105]

As a result, AI and machine learning industries are predicted to grow significantly within the next decade, with Australia's AI sector predicted to be worth $23 billion by 2025.[134] The Australian Government has committed to a number of reforms in response to the Productivity Commission's enquiry into data availability and use. This includes committing $65 million to reform the Australian data system and introduce a National Data Commissioner to oversee a data sharing and release framework.[135]

In healthcare, machine learning is set to have the greatest impact in diagnostic and decision-making support, as well as automation. As AI becomes more complex and advanced, so too will our diagnostic and preventative capabilities. For example, AI can play a role in identifying people at high risk of developing a chronic condition, and can help the older population who live independently or suffer from chronic diseases.[104] Some examples of new and emerging technologies in Australia are provided below.

Automation Within the next ten years, AI technologies may result in the automation of tasks such as triaging, predicting risk, screening blood samples or reviewing large amounts of new literature.[136] Increased automation of difficult or tiresome work will reduce the workload of healthcare providers but will also require a change in workforce capabilities as some skills are made redundant and new skills emerge.[104] Although AI will not replace healthcare professionals, it has the capacity to support clinicians in decision-making and data-mining activities to significantly reduce workload.

Drug discovery and research translation Drug discovery research is an emerging application of AI. Applying AI technologies in research may facilitate faster identification and translation of drug candidates.[128] For example, Australian researchers at Flinders University recently contributed to the development of a seasonal influenza vaccine that is believed to be the world's first human drug completely designed by AI.[121]

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Data management and storage It is predicted that up to 80 per cent of data is unstructured and is therefore difficult to use.[137] AI technologies have the potential to improve access to and use of unstructured data in order to improve diagnostic capabilities. Natural language processing is an emerging tool for processing large amounts of unstructured health text data, such as examination notes, clinical lab reports and discharge summaries.[138] The rapid increase in big data will require data to be easily linked up to secure and safe online platforms. Cloud-based storage will be used for various data storage and application purposes. For example:

- Doctors will be able to create and upload digital prescriptions to the cloud, and pharmacists will be able to download the information.[139]
- Development of genomic data storage and access will continue.[115]

The Melbourne Biomedical Precinct will build on its clinical and health informatics expertise to drive the integration and analysis of various streams of data.[140]

Equity of access to healthcare Assuming that ethical challenges are addressed, AI has the potential to make healthcare more accessible and equitable. AI-driven applications will be available to anyone with a smartphone, although this will require adequate digital infrastructure and literacy. It will be important to spread new technology to remote and regional hospitals to ensure that Australians have equal access to AI technology in places where access to specialist healthcare professionals is severely limited. AI technology should be adapted to platforms that are accessible to people with disabilities, older people, and people who are culturally and linguistically diverse.

Predictive, diagnostic and assistive technology Machine learning is already being applied as a diagnostic tool and is likely to evolve to include more complex diagnostic capabilities to tackle rare and dangerous conditions. The development of AI applications for use with existing medical imaging equipment, and within digital pathology, will revolutionise technology and the way in which data from these technologies is used. Fast data processing and greater accuracy in disease diagnosis are two benefits of integrating AI-driven software to existing imaging hardware.[141] For example, Queensland doctors recently contributed to an international study aimed at developing a machine learning algorithm capable of detecting heart attacks in the early stages. The algorithm (called MI)[3] incorporates age, sex and troponin concentrations to provide a measured assessment of a patient's condition for the early detection of heart attacks.[142]

Public health research CSIRO recently developed a web tool for the Black Dog Institute to analyse social media posts to map emotions. The WeFeel software uses language processing technology to analyse up to 27 million posts per day to support public health research on the impact of social, economic and environmental factors on mental health.[143] CSIRO's Data61 has also developed a program to track the spread of infectious disease, using Bayesian inference and machine learning techniques. The project aims to monitor the spread of infectious disease for biosecurity purposes and to monitor disease outbreaks in Australia.[120]

MACHINE LEARNING

Pacific Knowledge Systems in Sydney developed early machine learning-type technology in 1998 to facilitate automated pathology reporting, enabling most results to be reported automatically, with only a few exceptions requiring a specialist pathologist.[146]

CSIRO'S TeleMedC eye-screening test for diabetic eye disease uses machine learning technology to test patients with diabetes for diabetic retinopathy, combining eye images with clinical risk factors to enable early intervention and treatment of the disease.[147] Plans are currently underway to roll out the technology to 20 GP clinics in Western Australia.

Dementia Support Australia is using machine learning technology to monitor the severity of pain in patients with dementia, who are unable to self-report. The program, called PainChek, is the world's first smartphone-based pain assessment tool that uses facial recognition to detect pain-related expressions.[148] The idea originated at Curtin University in Western Australia and has been developed and commercialised by PainChek Ltd. The Australian Government has offered $5 million to support the national rollout of the technology in aged care facilities.[149]

FungalAI™ is a commercial venture founded by clinicians at the Alfred Hospital. It has generated a machine learning tool to support the diagnosis and treatment of invasive fungal infections. FungalAI™ is built on neural networks that use deep learning-based image analysis and natural language processing of chest CT reports to help diagnose fungal infections. The technology is currently undergoing validation in a multi-centre clinical trial at seven Australian hospitals and is being incorporated into a clinical trial for acute leukaemia in older patients, funded by the Medical Research Future Fund (MRFF).[150]

Up to 500 medical practices across several public health networks in Victoria and New South Wales contributed their pooled, de-identified primary care data to Outcome Health's POLAR DATA project, enabling the development of a predictive tool to help GPs determine a patient's risk of attending an emergency department.[151] The algorithm linked records of all patients admitted to an emergency department over five years in order to map their general practice visits, resulting in a decision-support tool that can be used by GPs. The tool was able to predict the risk of a patient attending an emergency department within the following month with equal or greater accuracy than other results previously published.[151]

ARTIFICIAL INTELLIGENCE IN CARDIAC ARRESTS

Monash University and Ambulance Victoria will be working on a project called Artificial Intelligence in Cardiac Arrests to help paramedics get to the scene of a cardiac arrest faster. The AI technology will run in the background of incoming emergency calls to monitor the conversation and identify signs of cardiac arrest. If there are signs, the technology will alert the call-taker to dispatch a high-priority ambulance and talk to bystanders.[152]

AUGMENTED REALITY ENABLING HANDS-ON LEARNING EXPERIENCES

Augmented reality can be used in healthcare to obtain detailed visualisation during surgical procedures, and to boost the training of medical students by enabling hands-on learning experiences.[144] It can also be used to prepare patients for treatment. Augmented reality uses a range of sensors (computer components or a camera) to project digital information, such as three-dimensional (3D) digital imagery or sounds, onto the existing environment. In medical education, virtual, augmented and mixed reality can aid with visualising physiology mechanisms and three- or four-dimensional (4D) structures in anatomy in space and time dimensions.[144] Augmented reality systems can allow surgeons to overlay medical images from computed tomography (CT) scans and magnetic resonance imaging (MRI) directly on a patient to get a detailed view of their internal anatomy.[145] Examples of emerging companies in this field include SmileyScope, which is developing a virtual reality experience for children who need medical procedures involving a needle; and Vantari VR, which is building software solutions to help healthcare professionals visualise, interpret and understand medical images. In the future, machine learning with AI could change user interfaces to create new models of analysis.

3.2. SMART DIGITAL TECHNOLOGIES

Smart digital technologies not only collect data, they are also connected and can exchange information. This section looks at three smart digital technologies: telehealth, networked medical devices, and mHealth. All of these technologies will reduce overall costs for the prevention or management of chronic diseases, and will improve patient mental health and lifestyles.[153]

3.2.1. Telehealth

Telehealth is defined as the use of telecommunication techniques for the purpose of providing healthcare or health education at a distance. It allows for virtual consultations between patients and healthcare professionals, using communication technologies such as video conferencing, messaging and mobile apps. Telemedicine involves the use of advanced telecommunication technologies to exchange health information and provide healthcare across geographic, social and cultural barriers.

Telemedicine involves the use of advanced telecommunication technologies to exchange health information and provide healthcare across geographic, social and cultural barriers.

Adopting telehealth nationally would bring significant benefits. Telehealth and telemedicine improve access to medical treatment and healthcare, and they remove barriers to healthcare such as distance, time, cost, and social and cultural barriers. They also enable the provision of care to individuals who cannot physically attend consultations, and they increase patient access to specialists. In addition, telehealth offers immediate and consistent care, which are services that patients value.[154] Evidence suggests that telehealth and telemedicine reduce mortality rates, improve health outcomes, and reduce financial burdens for patients and the healthcare system.

APPLICATIONS

Telehealth has several medical applications,[155] including real-time telehealth, 'store and forward' and remote monitoring.

- **Real-time telehealth** A real-time telecommunication platform allows instantaneous communication between patients and healthcare professionals – for example, via videoconference or telephone call.
- **Store and forward** Digital images, video or audio recordings are captured, stored and sent to a healthcare professional, who assesses the information and responds with feedback or opinions. For example, healthcare professionals could provide consultations to patients who have infectious diseases.
- **Remote monitoring** This involves the constant remote monitoring of a patient's vital signs, progress or predetermined physiological parameters (such as heart rate or blood pressure). It is also referred to as 'home telehealth'. The collected data is useful for patient care and medical decision-making.

Telehealth can be used to provide services to patients, such as monitoring between consultations and follow-ups; providing specialist opinions to regional clients; conducting an assessment or intervention; and managing chronic diseases. While it is most commonly used to provide care, it can also be used to deliver education, support, professional development and supervision to healthcare professionals. For example, telehealth approaches may be used to provide professional support to remote medical or allied health professionals, either by allowing specialists to observe and offer advice or expert opinion, or provide a clinical handover; or by allowing remote medical or allied health professionals to consult with specialists or seek a second opinion. Specialties that can make use of telehealth include radiology, psychiatry, obstetrics, pathology and rehabilitation.[156]

Telehealth can be particularly useful in enabling preventative health interventions, which rely on early patient engagement with healthcare professionals. In Australia's significant regional and remote populations, travel time and cost are significant barriers to seeking medical care. In this context, telehealth and telemedicine technologies play a key role in prevention and wellness, as they provide patients with the opportunity to have regular consultations with a healthcare professional without travelling long distances. This is particularly important for promoting patients' access to specialists.

Using telehealth to diagnose and monitor the health of older Australians has the potential to significantly improve health outcomes for residents in aged care. A telehealth trial conducted by CSIRO within a network of Australian aged care facilities showed a 53 per cent decrease in hospital admissions and a 40 per cent reduction in mortalities within the trial period. It also resulted in economic savings of 25 per cent for the healthcare system.[157] Healthcare services can provide access to monitoring and diagnostic equipment (such as X-rays, screening or imaging equipment), and the resulting clinical data can then be shared with specialists to inform the development of care plans.

Telehealth has also been found to be effective in empowering people with severe disabilities, enabling family caregivers to self-manage chronic health conditions, and providing mental healthcare services.[158, 159] Telehealth can also benefit other communities, including Aboriginal and Torres Strait Islander peoples, who experience a burden of disease that is 2.3 greater than among non-Indigenous Australians.[160] In particular, it is an important tool for closing the gap in health outcomes and providing equitable services to Aboriginal and Torres Strait Islander communities; remote or regional communities, ageing, disabled, and people who experience linguistic or cultural communication barriers.[161] For example, communication technologies such as voice-to-text (which uses natural language processing) allow individuals to command electronic notes verbally. Health applications and new monitoring technology will also advance the recovery and rehabilitation of patients at home, enabling them to record and transmit continuous, real-time monitoring data.

TELEHEALTH

TELEHEALTH TRIAL

A telehealth trial conducted by CSIRO within a network of Australian aged care facilities showed a 53 per cent decrease in hospital admissions and a 40 per cent reduction in mortalities within the trial period. It also resulted in economic savings of 25 per cent for the healthcare system.[157]

PLATFORMS

Examples of how telehealth technologies may be used are provided below.

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
Telecommunications technology will be used to conduct consultations or health assessments, collect data and facilitate data transfer.	Healthcare professionals will use monitoring technology and medical devices to assess patients' vital signs or physiological conditions, and they will use health data from multiple sources in order to determine the most suitable treatment.	Digital health technologies will be used to improve the coordination of care plans between multiple care providers (for instance, between metropolitan specialists and regional hospitals).

BARRIERS AND CHALLENGES

Australia is uniquely positioned to develop, testbed and adopt new telehealth technologies thanks to our geography, affordable and accessible technology, and established reimbursement system. For example, the Medicare Benefits Schedule (MBS) already supports video consultations for GPs, nurses, midwives, Aboriginal healthcare professionals and specialists. However, there are challenges, particularly slow uptake and costs.

Technology uptake has been slow due to a lack of coordinated approaches to integrating telehealth technologies outside of the public health system, as well as a lack of reimbursement for allied health professionals.[162] Also, the initial cost of equipment, including the cost of providing staff training and education, can prevent small health organisations and clinics from adopting telehealth technologies.

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

Trials in Australia have demonstrated the efficacy of telehealth in reducing mortality rates and improving health outcomes for regional and remote Australians, including in the Northern Territory, which has the highest proportion of Aboriginal and Torres Strait Islander peoples of any Australian state. The Northern Territory telehealth trial (2014–15) found that implementing telehealth consultations significantly reduced travel, increased consultation attendance rates and provided an estimated cost saving of more than $1.1 million.[53]

As part of the National Digital Health Strategy (2018–22), the Australian Digital Health Framework for Action aims to further embed telehealth into clinical practice by carrying out testbed projects to assess whether this model of care can be delivered more widely and consistently.[82]
Future telehealth technologies may include more comprehensive diagnostic and monitoring opportunities. Start-ups in this space include Birth Beat, a telehealth service that helps families develop a birth plan.[163]

Psychology, social work and counselling utilise telehealth and are well-suited to the face-to-face via video model. It is useful particularly for ongoing follow-up where the client and practitioner are already familiar with each other from face-to-face consultations.

3.2.2. Networked medical devices

Medical devices are technologies and equipment that are used at the point of care in hospitals, clinics and healthcare services; or by patients themselves at home, as part of their health management or on their body for fitness and lifestyle purposes. The Therapeutic Goods Administration (TGA) defines medical devices as those which are used on humans, have therapeutic benefits, and generally have a physical, mechanical effect on the body or are used for monitoring purposes.[164] Medical devices encompass a broad range of technologies, including clinical equipment for point-of-care diagnosis, surgery, treatment and monitoring; and patient-centric devices. The global market for medical devices is expected to have a compound annual growth rate of 5 per cent and to be worth US$800 billion by 2030.[165]

Most new medical devices have network capabilities as part of the IoMT (Internet of Medical Things). Networked medical devices are interconnected and communicate with other IT systems to collect, capture, stream, communicate and monitor real-time data on patients' vital signs or biological responses for the purposes of health management and diagnosis. They are remotely and wirelessly controlled by clinicians or by patients themselves.

Networked medical devices can be separated into the following categories:[169]

- **Wearables** for example, portable insulin pumps.
- **Implantable or embedded devices** for example, pacemakers
- **Stationary devices** for example, chemotherapy dispensing stations

The collection of health data by medical devices contributes to the growing volume of big data in healthcare, which in turn supports the development of improved health AI technologies, data analytics tools and novel medical device technologies. These technologies can transfer data to a remote centre, direct a patient to take a specific action, or automatically perform a function based on what the sensors are reading. For instance, insulin can be automatically administered if blood glucose is identified as elevated.[170]

WEARABLES

Previously geared towards consumer health enthusiasts, healthcare professionals are now beginning to adopt wearables for patient monitoring.[171] Wearables are worn directly on, or loosely attached to, a person.[172] They facilitate interaction between four areas: (a) a person's body, including body temperature and heart rate; (b) data loggers or portable units; (c) offline data analysis systems, including medical information systems; and (d) real-time monitoring systems that enable the visualisation of live data (for example, through portable devices or a remote monitoring centre).[173] These wearables are revolutionising biomedicine by enabling continuous, longitudinal health monitoring outside of the clinic.[171] They also facilitate algorithm development for automated health event prediction, prevention and intervention.[171]

Wearable technologies can be divided into two categories: external medical devices for patients, and devices for consumers (Table 6). External medical devices for patients are used for continuous health monitoring, follow-up and management, providing low-cost, clinically sensitive data to support more informed patient assessment.[172] Devices for consumers allow health, wellness, performance and fitness data to be collected, monitored, tracked and shared. The success of consumer wearables is in part due to their small and portable size, which allows them to be worn and used continuously. While smartphones are currently required to process the incoming data for most consumer wearables, it is conceivable that all processing functionality will be self-contained in the near future.[174]

Ultimately, smartphones and networked wearables will allow patients to remotely monitor their own health and provide data to healthcare professionals. This technology will also improve equity and access to healthcare by breaking down geographical and financial barriers.

A survey conducted by IQPC found that 43 per cent of healthcare professionals believe that wearable monitoring devices have the biggest potential to shape the future of healthcare, followed by AI (21 per cent) and robotics (14 per cent).[175] Research discussed in PricewaterhouseCoopers' (PwC) Wearable Future Report[176] found that 55 per cent of surveyed Australians owned a wearable device (devices for consumers), with health identified as the primary motivator for owning the technology.

THE INTERNET OF MEDICAL THINGS

The Internet of Things (IoT) brings together the physical and digital worlds by connecting computer devices to allow the transfer of data using networking technologies, such as 5G. Specific to the healthcare sector, the IoMT enables the communication and sharing of data between physical devices (mobile), sensors, medical devices, software (apps), electronics, applications, and healthcare systems and services.[166] There are three key IoMT capabilities: remote access for healthcare service delivery and patient monitoring; smart wearable technologies (wearables) using sensors; and applications to connect medical devices to healthcare IT systems for customised patient solutions, enabling health to be monitored in hospitals, houses and outdoor environments.[167]

The IoMT has the potential to enhance the quality of care for older people, people with disabilities, and culturally and linguistically diverse populations, and to relieve pressure on communities and healthcare providers. Applications include medication reminders and the monitoring of health indicators related to chronic diseases, such as vital signs, activity levels, glucose, heart rates and sleep. In rural and remote areas, remote access to these services will give patients and physicians better access to healthcare and facilities respectively.

In hospitals, IoMT platforms can help nurses and off-site doctors to monitor patients' vital signs continuously for early detection and care. Smart beds can self-adjust to provide a patient with the correct support and pressure without any manual intervention, and smart lockers can be used to deliver prescriptions and medication. The IoMT can also enable non-critical patients to be monitored from home, reducing costs and increasing healthcare access. For example, home medical devices can automatically upload data to the cloud-based hospital system, notifying the healthcare professional if the patient needs assistance. Many hospitals around the world have implemented smart devices to track vital health information and create a data repository that can help to guide diagnoses and care plan development.

Australia has extensive capability in smart medical technology solutions, and the IoMT has numerous applications in Australia's healthcare sector, from remote patient monitoring and service delivery to smart sensors and medical device integration. Application of the IoMT is already lowering costs, improving efficiency and bringing the focus back to quality patient care.[168] Geographic challenges coupled with a world-class R&D environment have created opportunities and driven advances in technology for the delivery of remote healthcare services.

TABLE 6
Two categories of wearable technologies for collecting patient data

WEARABLE CATEGORY	FUNCTION	EXAMPLE OF DEVICES
External medical devices for patients	Collect patient information, generate databases, monitor patients while in hospital and following discharge, and provide ongoing monitoring of patients with chronic conditions or frailty[168, 172]	• Monitoring devices such as skin patches, heart rate and blood pressure/glucose monitors, thermometers and fall-detection devices • Functional assistive devices including hearing aids, insulin pumps, personal alert or emergency call devices, and wearables for recovery from stroke or injury
For consumers	Deliver personalised, immediate and goal-oriented feedback based on specific tracking data obtained via sensors, and provide long-lasting functionality without requiring continual recharging[174]	• Fitness and wellness tracking devices to measure and encourage activity levels, such as GPS watches, pedometers, heart rate monitors, muscle activity sensors, sleep trackers, ultraviolet (UV) sensors and blood glucose trackers (from sweat) (Data may be obtained via digital cameras, location GPS, microphones, oximeters, Bluetooth, pressure and thermometers, camera clips, smartwatches or sensors embedded in clothing.)[174]

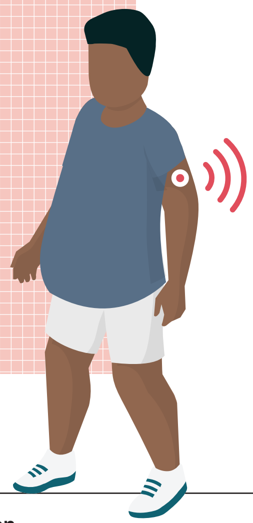
IMPLANTABLE TECHNOLOGIES

The TGA defines implantable medical devices as any device that is intended to be totally introduced into the human body, or to replace an epithelial surface or the surface of the eye by clinical intervention, and which is intended to remain in place after the procedure.[177] Broadly speaking, implantable devices are medical devices that can be implanted under the skin, or within the body, to maintain bodily functions or monitor physiological conditions. Implants are most often used in response to disease, illness or injury (such as hip replacements or cochlear implants), but they can also be used for prevention and wellness purposes by monitoring and maintaining bodily health and function (such as pacemakers or drug-eluting stents). Medical implants are commonly classified as neurological, cardiovascular, orthopaedic, electric, contraceptive or cosmetic, but they can also be used to combat organ dysfunction or disease, including cancer. Future implantable technologies may include medical chips and biosensors that store and transmit biological data or health information within a defined network.

MEDICAL SENSORS

WEARABLE & IMPLANTED SENSORS

Built into wearables and implanted devices, sensors can remotely collect safety and efficacy data. Sensors can be biological (for example, detecting blood, respiration or tissue) or non-biological (for example, detecting temperature, motion or electrical activity from the heart or muscles). Sensors have already been incorporated into more than 3,000 clinical trials globally.[178]



APPLICATIONS

While the idea of connecting medical devices to the network originally focused on location tracking and data reporting, the expansion of the IoMT has taken smart medical devices to the next level. Their ability to communicate with patients is already improving patient care outcomes; increasing engagement with, and uptake of, the technology; and enabling the collection of rich, real-time, biometric data, which offers valuable opportunities for patient-centred, coordinated care and applied clinical research.

Medical devices can be divided into three categories: therapeutic devices, diagnostic and monitoring devices, and injury prevention and rehabilitation devices. Of these, diagnostic and monitoring devices are expected to dominate the global market due to applications in prevention and wellness. Internet-connected devices have already been introduced to monitor and diagnose patients in various ways. In the hospital, a combination of radio frequency identification (RFID) tags, sensors, surgical instruments and other technology in medical devices is providing new levels of insight into patient wellbeing, as well as operational functions like sterilisation processes, inventory management and asset optimisation. From automated insulin pumps to diagnostic instruments that can interpret biological data, today's medical devices are smarter and more sophisticated than ever.

Assistive medical technologies have a range of applications for individuals, including people living in remote communities, people with disabilities, older people, people who are injured and people who are chronically ill. They can also assist healthcare professionals to provide care — for example, via surgical robots and decision-making support algorithms. There are four common types of assistive technologies:

- **Augmented communication technology** Voice-to-text or text-to-voice software, emergency call systems, audio-visual aids, speech synthesisers, modified keyboards and touchscreen technologies
- **Educational software** Text enlargers, word prediction, notetaking software and organisational tools
- **Functional devices** Feeding devices, dressing technology, support robots and virtual assistants
- **Mobility aids** Robotics, bionics, prosthetics, exoskeletons, wheelchairs, mobility scooters, walking aids, electric beds and patient transfer devices

The rise of health, fitness and wellness apps for smartphones and connected wearable devices means that the concept of digital wellness is becoming increasingly embedded in people's lives. Consumers are becoming more interested in managing their health and fitness, with activity trackers identified as the most popular wearable devices for consumers. At their most basic, these devices track steps, heart rates and sleep patterns, allowing an individual to analyse their activity or sleep habits and make changes to their behaviour to improve their health. Studies have indicated that the collection and analysis of an individual's data may have small positive effects on physical activity and weight loss.[179, 180] Valuable vital signs can be measured by wearables and used for diagnosis and monitoring, including ECG readings, heart rate, blood pressure, respiration rate, blood oxygen saturation, blood glucose, skin perspiration, body temperature and motion evaluation, as well as external and environmental parameters that may affect body response.[173] Wearable technologies also allow for continuous and remote monitoring of an individual, enabling them (and their clinicians) to keep track of their health and avoid unnecessary and costly visits to the doctor.[181] Data obtained from wearable technologies can be used for prediction, anomaly detection, diagnosis and support.

Newer activity trackers can also record increasingly advanced health data. For example, the Apple Watch Series 4 has approval from the United States Food and Drug Administration (FDA) to use electrical and optical heart sensors to take an electrocardiogram (ECG) and detect and notify the user of irregular heart rhythm. Using an accelerometer and gyroscope, it also has the ability to detect a fall and contact emergency services and emergency contacts if the individual remains unresponsive after 60 seconds.[182] Similar devices include the Verily Study Watch, a prescription-only wearable that can record, store, transfer and display single-channel ECG rhythms;[183] and KardiaMobile, an FDA-approved phone-tethered ECG.[179] Wearables are also used to support independent living through the use of personal alerts, voice panic detection, fall detection, inactivity detection, wander prevention and medication management.[184]

Implantable technologies are already widely used in the treatment of disease, illness or injury to maintain normal bodily function and follow-up, and implants to support visual, audio or cognitive dysfunctions are becoming increasingly advanced. For example, technologies such as hearing aids and cochlear implants can enable individuals with profound deafness to hear, including those born with congenital disabilities and people with injury-acquired hearing loss. Cochlear implants that restore hearing for individuals with profound deafness have also started to use low-energy Bluetooth for audio streaming of radio, phone calls or digital media.[185] Cardiovascular implants – such as electronic pacing devices, cardiac stents, structural implants, heart valves, ventricular assist devices and implantable monitors – have the potential to reduce ongoing treatment costs and significantly improve a patient's quality of life.[186]

The combination of implantable medical devices and wearable devices allows for real-time monitoring and response to a patient's condition. For example, Medtronic's Insertable Cardiac Monitor is implanted just under the skin to continuously monitor signals from the heart. When a patient experiences symptoms, a hand-held device can be activated to trigger the device to record the period during which symptoms occur, ensuring that real-time data is recorded.[170]

PLATFORMS

Examples of how medical devices may be used are provided below and in Figure 5.

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
Imaging devices that measure physiological parameters such as X-ray machines and MRI scanners can transmit images wirelessly to clinicians. The imaging and clinical data can be incorporated into the patient's EHR. Stationary medical devices and *in vitro* diagnostic devices can also be included in this category. These devices are increasingly being integrated with other healthcare applications to overlay patient data and imaging to facilitate faster and more precise clinical decision-making. Big data and health data analytics can be used to help medical imaging devices learn to recognise abnormalities in medical scans. Wearable, implantable and sensor technologies can provide continuous personal health data, which can be monitored and analysed for prevention and wellness, diagnosis and monitoring, and treatment purposes. The data can also be used in research and analysed to detect and track patterns in population health.	Collecting and analysing data from different sources can help healthcare providers to better understand which factors are affecting patient health outcomes. Smart medical devices bring together relevant data from many different sources – such as body-worn sensors, weather reports, medical records and diagnostic results – to make real-time recommendations. Consumer wearables can provide patients with personalised health data to assist with self-diagnosis and behaviour change interventions.[174] Wearables for patients allow for the collection, analysis and transmission of continuous personal health data, enabling personalised diagnosis and treatment.	Medical devices integrated with wireless connectivity are designed to be used in different environments, including homecare settings and network-connected hospitals. They could also be embedded in a patient's body. Networked medical devices enable improved monitoring and recording of vital signs, as they are less prone to human error. Such devices also allow easy data handling and can store a large volume of health data in an encrypted database for future reference, increasing the privacy of data storage. This can drastically reduce the workload for healthcare providers by closely monitoring patient health and taking quick action in the event of any major changes in the reading, resulting in improved patient outcomes.[56]

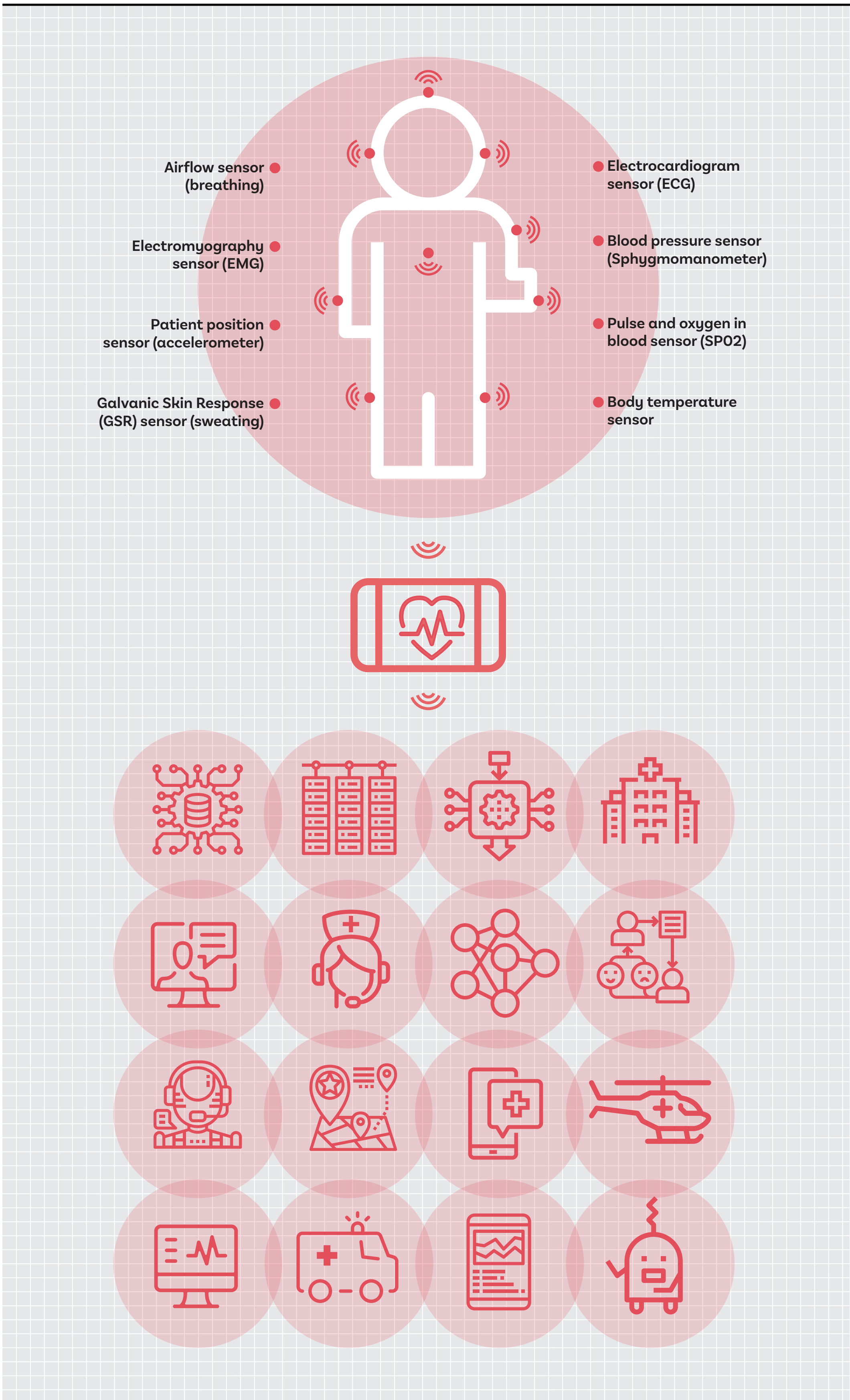


FIGURE 5
Digital and physical architecture for a remote healthcare monitoring system[187]

BARRIERS AND CHALLENGES

There are various challenges associated with using networked medical devices in Australia.

Equity and ethics Equity is an important consideration in the design and development of new networked medical devices. However, R&D is often performed without taking into consideration the diverse populations of end-users. Equitable data representation of different ethnic and geographic populations is necessary to produce technologies that provide equitable health outcomes for all users. Affordability is also an issue, as is the varying uptake of these technologies across different genders and ages.

Hardware and software Sensors should be optimised and designed to have a low power consumption when processing in real-time.[188] Suitable network bandwidth and system memory will be needed to process large amounts of data. Other issues include the flexibility of data volume, the lack of back-up systems, and a limited ability to connect to networks, such as public or mobile signals.[188, 189]

Literacy and education As health technology choices become wider and more varied, patient health literacy and education will become increasingly important. Patients will need to be provided with relevant information about new health technologies, including advice about data privacy and ownership, as well as health impacts and clinical outcomes.

Security Networked medical devices generate large volumes of data. As a result, it is essential that devices have mechanisms to protect data and prevent device hacking, and that these mechanisms are required in order to receive regulatory approval. Governments must also examine liability for data breaches in order to ensure the accountability of manufacturers. Medical device hacking (or 'medjacking') is the hacking of medical devices for the purposes of data theft or destruction, and is a major challenge facing the global medical device industry. The increasing use of smart or networked medical devices with interconnectivity with hospital IT systems and patient electronic medical records leaves patient health information highly vulnerable to cyberattacks and data theft.[190] The TGA assesses digital safety and the security of medical devices during the regulatory approval process for new technologies, but the evolving nature of cyberthreats and the increasing threat posed by IoMT technology mean that this is likely to become a greater challenge for the medical device industry in the next ten years.[191] Other security issues include system and data interoperability, safety and privacy, secure and robust IT frameworks, and secure operating systems.

Regulation of medical devices There is a strict regulatory environment for medical devices in Australia, with the TGA categorising risk based on global standards and requirements. It is essential that approved medical devices are safe and fit for purpose for both patients and end-users, including custom, customised and mass-produced medical devices. The TGA recently published an action plan for strengthening Australia's regulatory process for medical devices, monitoring and following up on current devices, and providing more device information to patients.[192]

Social challenges User attitudes and technological acceptance (or the lack thereof) may impede the uptake of networked medical devices.

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

Networked medical devices are becoming increasingly important to patient care. From prevention to treatment and rehabilitation, smart medical devices with network connectivity and data-capture capabilities are supporting clinical diagnostic abilities and improving patient health outcomes. While machines will never replace Australia's skilled medical workforce, tapping into the power of data analytics could significantly increase diagnostic speed and accuracy and enable healthcare providers to spend more time on patient care and communication, resulting in improved quality of patient care. In the next ten years, interoperable health data will be increasingly used for R&D, and there will be greater coordination of patient care between healthcare professionals and patients. IoT-enabled asset tracking and inventory management systems are expected to double worldwide by 2020, resulting in improved services for the patient and more efficient hospital operations.[193] Examples of emerging medical device technologies that will use the IoMT are shown in Table 7.

TABLE 7
Examples of emerging medical device technologies

EMERGING CONNECTED DEVICES	FUNCTION	EXAMPLE OF DEVICES
Equipment for expert use: Portable, high-performance diagnostic equipment	Facilitate the diagnostic process, especially for time-sensitive medical conditions	3D scanners
Equipment for expert use: automated equipment	Streamline processes and improve the accuracy and safety of patient diagnosis and treatment	Delivery of drugs, high-performance scanners and remote-controlled surgical equipment
Home monitoring devices	Enhance safety and standards in outpatient care	Fall detectors and home treatment devices
Wellness products	Empower patients to manage their own health	Fitness bands and smartwatches

As wearable, implantable and sensor technologies become more advanced and mainstream, clinicians will increasingly use wearables to monitor a patient's health.[195] According to a 2017 report by Accenture Consulting, 91 per cent of healthcare providers indicated that using wearable technologies to monitor patients would be part of their wellness and prevention initiatives.[196] In the United States, demand for wearable technologies to monitor health conditions has already prompted the FDA to create a digital health software pre-certification pilot program for leaders and innovators in the medical device and technology sectors to reduce the time it takes to get technology to market.[197]

Stethee is a novel stethoscope developed by M3DICINE, an Australian company. This wireless, AI-boosted stethoscope pairs with a mobile device app to quickly capture and analyse heart and lung data. It can both record and transmit data, facilitating longitudinal studies and remote diagnosis and measurement.

By 2024, the global wearable devices market is forecast to reach $67 billion in value.[198] Thanks to Australia's strong medical device manufacturing industry, we are likely to benefit from this positive economic outlook if small, early-stage ventures are supported to compete in the device market. Emerging wearable and implantable technologies include micro-wearables, dermal sensor patches, brain–machine interface technologies and implantable microchips. Indeed, Synchron (a spin-off from the University of Melbourne) has already reported the first successful implantation of a minimally invasive neural interface device in a person.[199] This technology is expected to eventually allow users to cognitively control assistive devices such as wheelchairs or robotic limbs, and to transmit real-time brain activity data to software platforms.

3.2.3. Mobile health apps

mHealth refers to the use of mobile and wireless communication technologies to improve healthcare delivery, outcomes and research.[200] It can be used for disease surveillance and monitoring, treatment support, epidemic outbreak tracking and chronic disease management, and to educate consumers about preventative healthcare services.[201] When combined with connected wearable devices, mHealth technologies provide a convenient and inexpensive way of continuously tracking and managing certain conditions without patients having to see their healthcare provider. This can be useful for consumers who do not have direct access to healthcare providers. Mobile applications that support sleep, fitness, activity and nutrition are already engaging individuals to take charge of their health.[104]

In 2018, the global mHealth app market was valued at US$12.4 billion, with a projected compound annual growth rate of 44.7 per cent to 2026.[202] With 89 per cent of Australians now owning a smartphone,[203] mHealth is anticipated to play an increasingly large role in engaging patients in self-care and supporting improvements in patient wellbeing and management, and in the optimisation of care delivery. The rise of mobile devices is also leading to rapid growth in medical software apps, which can assist healthcare professionals with important tasks such as information and time management, communications and consulting. However, not all apps are standardised and validated, which prevents their proper use and integration into medical practice.[204]

Within healthcare, smartphone apps fall into two main categories:[205]

- **Health apps** non-invasive monitoring programs that are unregulated and relate to the general health and wellbeing of the individual.
- **Medical apps** classified as medical devices, requiring approval from regulatory authorities (for example, the TGA). These apps provide diagnostic tools and remote monitoring and can include sensor-based applications.

To date, there are three third-party authorised apps connected to My Health Record that have secure, view-only access (Table 8). These mobile apps allow the viewing of some My Health Record content on a smartphone or tablet.

TABLE 8
Authorised apps on My Health Record as of February 2020[206]

NAME OF APP	COMPANY	EXAMPLE OF FEATURES
HealthEngine	HealthEngine Pty Ltd	Used to book health appointments
Healthi	Chamonix Health Solutions Pty Ltd	Allows Australian residents to access their family's personal health records in the national My Health Record system
HealthNow	Telstra Health	Allows users to talk to a doctor at any time and schedule consultations by phone with specialists, mental health professionals and others

APPLICATIONS

Apps can help a patient and their healthcare professional(s) to monitor, maintain and improve the patient's health, increasing the personalisation of healthcare and shifting the focus to wellness and prevention. For example, smartphone apps are widely used by and recommended to patients with diabetes for self-monitoring of dietary and physical activity behaviours.[207] Apps can also give doctors a mobile data source while they consult with patients, or a mechanism to consult patient records while mobile. Chatbots, or AI conversation partners, are a communications tool that run on smartphones to support people living with conditions that affect language and communication, such as autism spectrum disorder.[84]

An incredible range of mobile apps are available to assist with health, some of which have been shown to improve health outcomes using real-time mobile technology interventions[208] (Table 9). Examples of mobile apps range from dietary, sleeping and physical activity apps to apps that assist with chronic illness management, make appointments, provide medical information, and enable real-time disease surveillance to monitor outbreaks and implement responses.

TABLE 9
Examples of types of app

TYPE OF APP	DESCRIPTION
Booking apps	Booking apps allow a patient to make an online booking with a healthcare facility, such as the 13SICK app.
Clinical assistance apps	Clinical assistance apps allow clinicians to check digital health records, access lab results, and enhance appointments through patient education or by viewing images (for example, the AllScripts app).
Healthcare facility apps	Healthcare facility apps are created by a particular facility to provide information to the consumer (for example, the Royal Children's Hospital, Mebourne, Clinical Practice app).
Medical reference apps	Medical reference apps are designed for healthcare professionals to provide clinical reference information and clinical decision support at the point of care to improve patient outcomes. Medical reference apps provide references for diseases, diagnostics, treatments, drug information, medical news and patient management (for example, the Australian Medicines app).
Reminder apps	Patient use reminder apps to remind them to take medication, record what medications they have taken, or prompt them to attend appointments (for example, the Save the Date to Vaccinate app).
Specialty apps	Specialty apps provide a range of tools, from continuous professional development activities to providing information on side effects (for example, the Ausmed app).
Patient portal apps	Patient portal apps provide a patient with access to EHRs and healthcare information (for example, My Child's eHealth Record).
Patient education apps	Patient education apps include personal health monitoring apps, such as the Diabetes Australia App.
Telehealth and monitoring apps	Monitoring apps allow a healthcare professional to remotely monitor the behaviour or symptoms of patients (for example, the HealthNow app).
Wellness apps	Wellness apps include diet and fitness apps. They are primarily used by consumers rather than healthcare professionals (for example, Fitbit).

PLATFORMS

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
Mobile apps can be connected to My Health Record, allowing more information to be collected, managed and analysed.	Behaviour and statistics can be tracked through mobile apps to assist with investigations into genetic links. For instance, the PPD-ACT app is part of an international research program aimed at women suffering from post-partum depression.[209]	Mobile apps can remotely monitor and track health data.

BARRIERS AND CHALLENGES

There are two main challenges associated with using mHealth in Australia: gaps and limitations in mHealth app research, and the credibility of mHealth apps.

Research Rapid growth in mHealth apps has resulted in confusion among healthcare providers and the public about which products rely on evidence-based medicine.[210] This presents a risk to the consumer, both through the potential for over-diagnosis, self-diagnosis and the creation of siloed data, and through the potential to damage relationships with healthcare professionals.[203] Researchers at Bond University recently conducted a study to identify gaps and limitations in mHealth app research, and to evaluate the effectiveness of 'prescribable' mHealth apps (defined as apps that are currently available, have been proven effective, and preferably do not require dedicated central servers and continuous monitoring by medical professionals).[211] Through an assessment of systematic reviews of already published randomised control trials of prescribed mHealth apps, it was found that only 23 randomised control trials of currently available apps had been conducted, fewer than half of which demonstrated that the app had a meaningful effect on health.[211] To reduce the risk of consumers using and relying on data created from these apps, the Digital Health Guide was developed to help healthcare professionals guide patients in the safe and appropriate use of mHealth apps, and to navigate the confusing space of digital health apps and websites.[203]

> TGI developed its first SMARThealth platform – HealthTracker – in 2011. HealthTracker provided clinical decision-support tools for cardiovascular disease management and prevention in primary healthcare services. Integrated with electronic medical records, it was designed to help healthcare professionals implement recommendations from clinical guidelines and make it easier for patients to understand their risks. Following the successful trial of HealthTracker, the SMARThealth concept was extended to a tablet-based system that could be used in low-resource settings. Over the last few years, TGI has further developed the SMARThealth system to support the detection and ongoing management of high-risk non-communicable diseases and related risk factors, adaptable to any global setting.[219]

Reputation App credibility is a major barrier. There is scepticism about mHealth apps, and there is a need for central oversight, guidance and even subsidisation to guide consumers and healthcare professionals when using this technology.[212] There is also a need for greater regulation, transparency of third-party data sharing and the development of privacy-compliant apps.[213]

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

There is an opportunity in app design to promote sustained and significant lifestyle and behavioural change,[214] particularly as mHealth interventions for physical and mental health are beginning to show efficacy.[215] The global mHealth apps market is expected to reach a value of US$111.1 billion by 2025.[216]

Australian-made apps are already available, including the CancerAid and DreamLab apps. CancerAid offers an app and coach program to support and motivate cancer patients, educate service providers and improve health outcomes.

IDLE PHONES

Utilising the processing power of idle phones

DreamLab uses the processing power of an idle phone to work towards a cure for cancer while people sleep, connecting the processors of users' smartphones into a problem-solving network. To date, the application has been downloaded more than 320,000 times and has contributed to solving two cancer-related research problems.[217]

Ambulance Victoria recently released GoodSAM, a new app for registered first responders to provide medical support in response to nearby alerts. Individuals can use the app to alert nearby responders if they are experiencing cardiac arrest, or to identify the nearest automated external defibrillator.[220]

Mobile computing will continue to grow as the number of smartphone users increases, and mHealth will almost certainly become part of hospital communication, patient education and follow-up. Areas of focus for future development include mobile telemedicine, disease surveillance and decision-support systems.[208] Efforts are also underway to enable doctors to prescribe via apps, although more evidence is needed to improve the credibility of such apps. mHealth is also prevalent in clinical trials, with pharmaceutical companies looking to detect and log patients' medical use to improve adherence with connected drug delivery platforms.[218]

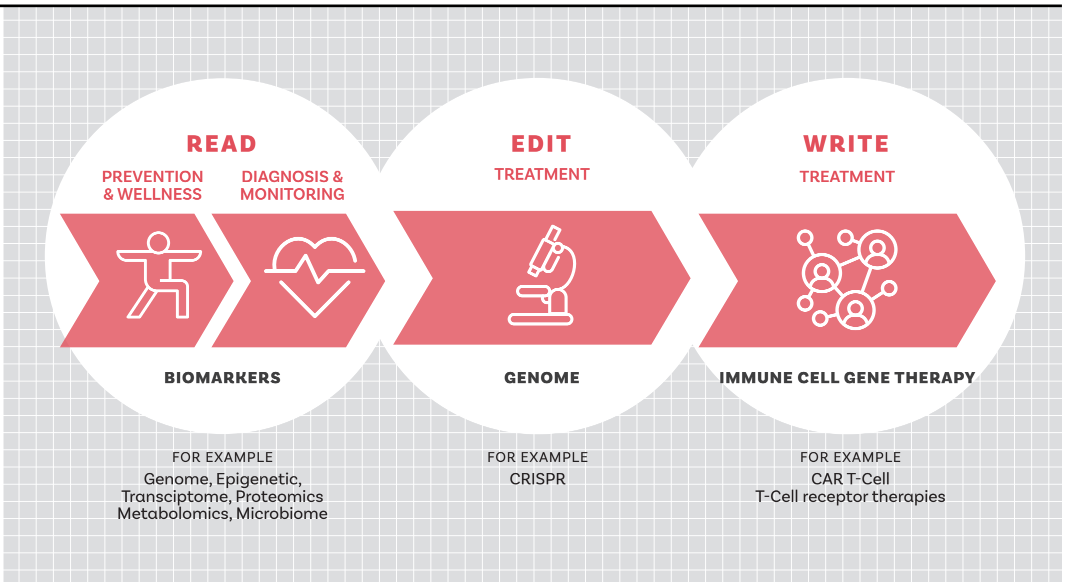
3.3. ADVANCED BIOTECHNOLOGIES

Scientific progress in biotechnology is advancing modern healthcare. The Organisation for Economic Co-operation and Development (OECD) defines biotechnology as the application of science and technology to living organisms in order to alter living or non-living materials for the production of knowledge, goods and services.[221] This includes DNA/RNA, cell and tissue culture and engineering, process biotechnology techniques, bioinformatics and nano-biotechnology. This section discusses omics, gene and cell therapies, bioprinting, and combination drug and device products.

3.3.1. Omics technologies

Omics is a field of precision technologies that broadly encompasses genomics, proteomics, epigenetics, transcriptomics and metabolomics (Figure 6). Following the human genome project and the invention of next-generation sequencing, omics technologies are being applied in physiology and disease at the molecular level (DNA, RNA, protein and metabolites).[222] Advances in omics capabilities and knowledge of the human genome are key to the development of precision medicine and a patient-centred approach to healthcare. Although omics technologies often refer specifically to genomics, diagnostic and preventative medical approaches can be improved through the incorporation of other omics approaches, as well as environmental and behavioural data, in order to provide a more holistic diagnostic approach.[23]

FIGURE 6
Omics technologies and related applications



Various sequencing methods have been developed over the years to find and detect biomarkers, particularly genes and proteins that are known to cause disease. The identification of genetic biomarkers of disease is commonly performed by Sanger sequencing. Technologies used in genomic studies include application of high-throughput sequencing and third-generation long-read sequencing (nanopore technology). [223, 224]

APPLICATIONS

At present, omics technologies are primarily focused on the universal detection of genes (genomics), mRNA (transcriptomics), proteins (proteomics) and metabolites (metabolomics) in a specific biological sample.[225] Omics technologies offer a highly specific characterisation of tissues at a given point in time, in relation to overall physiology,[226] using specific biomarkers as reference points from which changes in tissues or biological systems can be detected.

The primary application of genomics lies in predictive and diagnostic medicine for infectious disease and chronic diseases, such as cardiovascular disease, cancer and type 2 diabetes.[227] However, genomic technologies also have the potential to be used in the identification and monitoring of pandemic disease outbreaks and the spread of multi-drug-resistant bacteria. At the individual level, omics data can be used to predict patient responses to drugs via pharmacogenomics, and the identification of prognostic biomarkers can help to chart the likely course of a disease.[228] Omics technologies are also useful tools for monitoring changes in biological samples (in terms of gene regulation, protein expression and metabolite concentrations) to characterise biological pathways and response to treatments.

Omics technologies can be applied to support prevention and wellness in healthcare by providing a holistic overview of patients' risk of disease, and by identifying recessive alleles that may be used to predict the risk of rare or inherited genetic diseases in offspring. In addition, they can be used to advise on appropriate diets, supplements, exercise and lifestyle changes that will up- or down-regulate gene expression and keep individuals healthy longer. Whole-genome sequencing can help in determining the best course of treatment for patients – for example, determining cancer treatments or creating designer DNA vaccines to target emerging infectious diseases such as Ebola and Zika.[229] In 2019, next-generation genome sequencing played a significant role in identifying a new subtype of the human immunodeficiency virus (HIV): HIV-1 Group M, subtype L.[230] The application of multi-omics sequencing has the potential to identify multiple biomarkers (including minor contributors to a common disease) and support novel diagnostics, allowing targeted therapeutic intervention, including for individuals with genetic variations or rare diseases.[9, 231, 232]

PLATFORMS

Examples of how omics technologies may be used are provided below.

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
Bioinformatics and computational infrastructure can be used to capture, analyse and process large volumes of genomic data.[237] Using online repositories such as GenBank, publicly available collections of DNA sequences are made available for research purposes.[238]	Omics technologies are the cornerstone of precision medicine as they are used to identify patient-specific biomarkers to determine the cause of disease and the most effective treatment for individual patients.	Genome mapping can be used to treat a patient holistically, taking into consideration their likelihood of developing certain conditions and acting preventatively.

BARRIERS AND CHALLENGES

There are four challenges associated with the deployment of omics technology in Australia: the cost-effectiveness of genomic sequencing, the need to handle large volumes of data, the ethics of genetic testing and the availability of required skills.

Cost-effectiveness The cost of genomic sequencing is a barrier to universal uptake of sequencing technologies.[236] Next-generation sequencing has reduced the cost of sequencing an individual genome to less than $1,000,[239] but this cost still limits access to the technology. The creation of inexpensive and rapid diagnostic devices (such as gene chips and microarrays, which are able to perform detection or diagnosis using small amounts of a biological sample) may overcome the financial barriers to accessing certain types of genetic testing.[240]

GENOMICS IN AUSTRALIA

The National Health Genomics Policy Framework and Implementation Plan 2018–2021[233] sets out national priorities for genomic activities for Australia, including a person-centred approach to genomics, workforce and skills development, the development of cost-effective genomic technologies, and the responsible collection and use of genomic data. In 2018, the Australian Government committed $500 million over ten years to the MRFF's Genomics Health Futures Mission. Support includes new and expanded clinical studies of rare diseases, cancer and complex conditions, and community dialogue to understand the privacy, legal, social and familial effects of genomics.[234]

Other organisations working towards the application of genomic approaches in clinical practice include the Australian Genomics Health Alliance (Australian Genomics), a national network of clinicians and researchers.[234, 235] Spin-off research collaborations and products are already benefiting, informing and empowering patients,[236] and in the next ten years these collaborations and products will advance precision medicine.

AUSTRALIAN CAPITAL TERRITORY
Canberra Hospital
The Australian National University
National Centre for Indigenous Genomics

NEW SOUTH WALES
Australian Institute of Health Innovation, Macquarie University
Centre for Genetics Education
Children's Cancer Institute
Children's Medical Research Institute
Garvan Institute of Medical Research
Genome.One
Hunter Genetics
John Hunter Children's Hospital
Kinghorn Centre for Clinical Genomics, Garvan Institute
Liverpool Hospital
Nepean Hospital
NSW Health Pathology
Prince of Wales Hospital
Royal Hospital for Women
Royal Prince Alfred Hospital
St Vincent's Hospital Sydney
Sydney Children's Hospitals Network
The Kinghorn Cancer Centre, Garvan Institute
The University of Sydney
University of New South Wales
Victor Chang Cardiac Research Institute
Westmead Hospital

NORTHERN TERRITORY
Royal Darwin Hospital

QUEENSLAND
Diamantina Institute
Genetic Health Queensland
Griffith University
Institute for Molecular Bioscience
Pathology Queensland
Princess Alexandra Hospital
QIMR Berghofer Medical Research Institute
Queensland Children's Hospital
Queensland Genomics
Queensland University of Technology
Royal Brisbane and Women's Hospital
The University of Queensland
The Wesley Hospital

SOUTH AUSTRALIA
Centre for Cancer Biology
Royal Adelaide Hospital
SA Genomics Health Alliance
SAHMRI
SA Pathology
The University of Adelaide
University of South Australia
Women's and Children's Hospital

TASMANIA
Royal Hobart Hospital

VICTORIA
Austin Health
Genetic Support Network of Victoria
Melbourne Bioinformatics
Melbourne Genomics Health Alliance
Monash Health
Monash University
Murdoch Children's Research Institute
Peter MacCallum Cancer Centre
The Alfred
The Florey Institute of Neuroscience and Mental Health
The Royal Children's Hospital
The Royal Melbourne Hospital
The Royal Women's Hospital
The University of Melbourne
Victorian Clinical Genetics Services
Victorian Comprehensive Cancer Centre
Walter and Eliza Hall Institute

WESTERN AUSTRALIA
Fiona Stanley Hospital
Genetic Services of Western Australia
Harry Perkins Institute of Medical Research
King Edward Memorial Hospital
PathWest
Perth Children's Hospital
Royal Perth Hospital
Sir Charles Gairdner Hospital
Telethon Kids Institute
University of Western Australia

NATIONAL PARTNERS
Australian Genome Research Facility
BioGrid Australia
Bioplatforms Australia
CSIRO
FH Australasia Network
Genetic and Rare Disease Network
HeartKids
Kidney Health Australia
Mito Foundation
National Computational Infrastructure
Poche Indigenous Health Network
Rare Cancers Australia
Rare Voices Australia
SWAN Australia

PROFESSIONAL BODIES
Human Genetics Society of Australasia
Royal Australian and New Zealand College of Obstetricians and Gynaecologists
The Royal Australasian College of Physicians
The Royal College of Pathologists of Australasia

INTERNATIONAL PARTNERS
Baylor College of Medicine
Broad Institute of MIT and Harvard
Genomics England
Osaka University
UCL Great Ormond Street Institute of Child Health
University of Oxford

GLOBAL PARTNERS
Global Alliance for Genomics and Health
Global Genomic Medicine Collaborative

Data handling Genomics generates up to 30GB of data for an individual human genome,[236] and collecting and managing large amounts of genetic data on individual patients will be a challenge.[240] If the multi-omics approach is applied, even larger amounts of data will be generated, meaning that analysis would rely on parallel advances in data science research.[232] Another challenge is developing better systems to rapidly assess a patient's genetic profile.[240] Australia still needs a universal system for storing and sharing data, although Australian Genomics is developing platforms for collaboration and responsible and ethical data sharing.[236] Integrating omics data with registries of non-omics data – such as epidemiological and clinical (EHR) data – carries some challenges, including the correlation and understanding of the interaction between data types, as well as the lack of standardisation of non-omics data.[241]

Ethics of genetic testing There are ethical, social and practical issues to consider when undertaking genomic tests in healthy patients. In Australia, for example, medical professionals do not recommend testing genes linked with Alzheimer's in healthy patients.[9] Consent is also a concern. Current patient consent systems are mostly paper-based rather than digital and therefore have limited accessibility and interoperability. The issue of consent is also complicated by the potential use of genetic information for future research. Australian Genomics is exploring the concept of 'dynamic consent', where patients can use an interactive site to access, monitor and make changes to health information, including how their genomic data is used in research.[236]

Skills availability The transition of next-generation sequencing to clinical settings will require a significant increase in the skills needed for omics technologies. In Australia, there is already growing demand for genetic counsellors and geneticists,[236] which may prompt the introduction of more educational programs and university courses. A 2018 Australian Genomics study on education and training for the Australian clinical genomics workforce found that Australia has an estimated 59 relevant education activities or resources: 20 postgraduate genomics courses or subjects, 37 substantive programs, and two massive open online courses.[242]

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

Australia has strong R&D capabilities in omics technologies (ACOLA's report on precision medicine provides a useful overview of Australia's research, clinical and industry strengths and opportunities in this area).[9] Recently, a Queensland-based collaboration was awarded $2.6 million in federal funding for a project involving the use of AI in cancer treatment. The project aims to use AI to tailor personalised cancer treatments based on patients' genomic information, with the aim of determining the most effective treatment on an individual basis.[126]

Advances in genomic technologies have led to more research on the characterisation and analysis of the human microbiome. The microbiome is the ecosystem of micro-organisms (including bacteria, archaea, fungi and viruses) that live symbiotically within the human body. Microbiomics is rapidly advancing our understanding of the human microbiota's role in disease, and how manipulation of the microbiome can improve health and wellbeing. Microbiome testing is primarily geared towards prevention and wellness; for example, the characterisation of gut health can inform behaviour, diet and lifestyle factors, and can help individuals engage with their own health through management of their diet, lifestyle and exercise.[243] The identification of bacteria (while a disease is active) also provides an opportunity for microbiome diagnosis and treatment for chronic diseases and acute conditions,[244] with next-generation sequencing providing an alternative to traditional bacterial culture tests. The ability to sequence DNA bacteria and accurately identify their contribution to diseases will help in the design of treatments that only attack pathogenic bacteria.[244]

Australia has strong capabilities in microbiome R&D in the healthcare sector. Australia's first Microbiome Research Centre opened in 2019 and is dedicated to studying the microbiota in health and disease.[245] The centre is a collaboration between the St George & Sutherland Medical Research Foundation, the University of New South Wales and the South-East Sydney Local Health District. Its research will focus on cancer, women and children's health, infection, immunity and inflammation, critical care, and mental health and neuroscience.

> Behavioural and cultural changes are needed to support transformations in health, but people and systems do not tend to react well to transformative change. They are, however, susceptible to 'nudges'. Nudge theory is a concept in behavioural science that proposes positive suggestions to influence the behaviour of an individual. For example in the health space, DnaNudge suggests better lifestyle choices based on an individual's unique DNA, which is matched up with the nutritional values of manufactured food products to deliver personalised food recommendations, using a wearable band and mobile app.

3.3.2. Gene and cell therapies

Gene and cell therapies are targeted treatments. Gene therapy is an experimental approach that uses genetic information to treat or prevent disease. Gene editing and therapies offer opportunities for new approaches to disease management and treatment, rather than relying on traditional drug or surgical intervention. These approaches work by controlling gene expression or introducing functional genes into a patient's genome in order to treat, prevent or cure disease, including cancer, viral diseases and inherited disorders. Cell therapies are complex precision treatments that use a patient's own cells to fight disease.

There are four types of gene therapy (Figure 7), which can be classified as either somatic (gene therapy where effects will not be passed onto children) or germline gene therapy (implying that subsequent generations will carry the genetic change).

FIGURE 7
Summary of gene therapy applications[246]

Examples of gene-based therapies are provided below.

- **In vivo or ex vivo administration of non-viral (such as nanoparticles) or viral vectors for gene delivery** [247,248] Retroviruses, adenoviruses, herpes simplex, talimogene laherparepvec (T-VEC; also known as Imlygic) and vaccinia are examples of viral vectors – deactivated viruses that transfer new genetic material to cells.
- **Genome editing using enzymes to cut and edit DNA at specific sites to either insert, delete, replace, remove or modify a DNA sequence** Different types of genome editing nucleases that are currently used in genome editing include the well-known DNA cutting enzyme nucleases Cas9 and Cas12a that derive from the Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), zinc finger nucleases (ZFNs) and transcription activator-like effector-based nucleases (TALEN).[249]
- **Immune cell therapy** Patient cells are genetically modified ex vivo and then re-introduced into the patient's body to deploy engineered immune responses, boost the native immune response or suppress features of immune function. Immune cell therapy includes cell-based immunotherapy techniques such as chimeric antigen receptors T-cell (CAR-T) therapies, T-cell receptor therapies, natural-killer cell therapies, tumour-infiltrating lymphocytes and marrow-derived lymphocytes.[250]

APPLICATIONS

The applications of gene therapies and cell engineering approaches are broad, from treating cancer and acquired diseases to congenital or rare diseases and conditions. The primary applications of gene editing or gene therapy approaches include:

- Replacing a mutated gene that causes disease or dysfunction with a healthy copy of the gene
- Inactivating a mutated gene to prevent expression
- Introducing a new gene into the genome that might prevent or cure disease
- Genetically modifying immature immune cells to fight disease or restore immune system function

The most widely known application of gene-based therapies is the CRISPR-Cas9 gene editing technology. CRISPR has broad applications in healthcare, from treating inherited genetic disease to reprogramming immune cells to attack malignant tumours.[251]

Genetic data can be used in predictive care and can help to identify diseases such as emerging, persistent, chronic and individual genetic variations. Translational bioinformatics can be used to study genomics for the development of personalised disease management and interventions.

PLATFORMS

Examples of how gene therapy technologies may be used are provided below.

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
Through the use of AI-driven programs, a large volume of genomic data can contribute to training and developing algorithms to study connections between genes and disease states. It can also help to determine appropriate gene therapy approaches for preventing or curing disease.[8]	Genetic technologies and cell engineering are the most advanced precision medicines currently available. Using genome or whole-exome sequencing and CRISPR gene editing techniques, healthcare professionals can develop the most targeted gene therapy approach for an individual patient, thereby optimising treatment on an individual basis.	The use of sequencing technologies to improve patient care is a key feature of gene-based approaches to treatment. By using a patient-centred approach to treatment design, improved patient care outcomes are possible.

BARRIERS AND CHALLENGES

The deployment of gene therapy technology in Australia faces regulatory, social and ethical challenges.

Regulation Evidence of safety, quality and efficacy is required for all new products. Regulatory agencies will have to balance the rapid and agile certification of new technologies with safety and proven effectiveness. Breaking new ground in precision medicine regulation, the TGA approved Australia's first CAR-T therapy in 2018: Novartis' CAR-T product, Kymriah® (tisagenlecleucel), for the treatment of B-cell precursor acute lymphoblastic leukaemia.[252]

Social and ethical There are a number of social and ethical issues associated with the adoption of gene and cell therapy technologies. The analysis of individual genomic information raises questions about data privacy and the possibility of genetic discrimination by health or life insurance providers in the future. Data ownership and privacy are important considerations when designing and implementing new sequencing technologies for clinical purposes.

Germline genetic modification of human sperm, eggs and embryos is formally prohibited in most countries. However, the development of ethical frameworks for genetic research in these areas is needed as research advances towards greater clinical application of these technologies.

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

The global market for precision medicine is growing rapidly. In 2017, the United States FDA approved more precision medicines than in any other year, three of which were the first gene therapies ever approved by the FDA. One of the approved drugs was Luxturna™, developed by Spark Therapeutics for retinal dystrophy. This is the first drug for the treatment of a genetic disease.[253]

Australia is a major player in gene editing and gene therapies worldwide, building on a strong medical research and life sciences sector and skills in medical manufacturing and R&D. For example, Australia is the sixth-highest publisher of CRISPR-based publications globally.[254] Precision medicines (including genetic testing, gene editing and engineered cell therapies) will see greater market approval and subsequent clinical application in Australia in the future, resulting in improved tailoring of medical care and better patient outcomes.

> New technologies in medical imaging include the development and improved safety of novel 'nano-diagnostics'. Instead of contrast dye, patients could be imaged using nanomaterials based on magnetic, adaptable, acoustic, nuclear and optical properties.[255] Known as in vivo imaging, nano-diagnostics can produce high-resolution and high-specificity molecular imaging.

3.3.3. Bioprinting

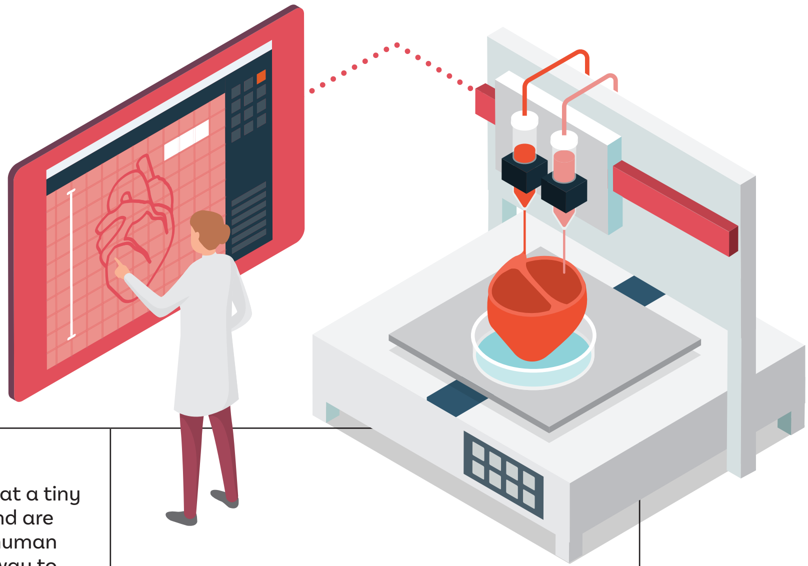
Bioprinting is the application of 3D printing technology to produce medical products, tissues or prosthetics for research or clinical applications. Data from medical imaging techniques – such as X-rays, CT scans, MRI scans and ultrasounds – is often used to generate a digital 3D model, which is subsequently fed into a 3D printer. 3D printing then creates products from this digital model by successively adding material in a precise, layer-by-layer approach.

Australia's experience in advanced manufacturing has been favourable for the integration of additive manufacturing applications in the healthcare sector. Australia is at the forefront of metal fabrication services in 3D printing, including the production of bio-compatible bone replacements, moulds and models for casting, affordable metal-fabricating 3D printing hardware and prototype production.

APPLICATIONS

3D printing technology is gradually revolutionising the healthcare industry by streamlining supply chains, reducing inventory requirements, lowering production costs and driving new intelligent lightweight designs. It is also being used for organ printing, producing cells and biomaterials individually or layer by layer to construct tissue-like structures.[256] This can facilitate the creation of replacement human organs, bones, cartilage and skin.[257]

There are numerous applications of 3D bioprinting for advanced manufacturing in healthcare, including the following:



Bioprinting tissues and organoids

3D printed 'organoids' that mimic organs at a tiny scale can be used for medical research and are being trialled as cheaper substitutes for human organ transplants. Efforts are also underway to develop 3D printed skin grafts that can be applied directly to burn victims.[258] 3D printed tracheas and tracheal splints are already helping newborns with severe breathing problems,[259] and bioprinting could potentially simplify pharmacology and provide solutions for administering multiple drugs. A 3D printed 'Polypill' that can store multiple drugs with different release times (which dissolve in a timed and controlled manner) can help ease issues of diverse drug interaction for patients with multiple ailments.[260]

Custom-made prosthetics

Patients can scan their own limbs to create a more natural fitting prosthetic, which can then be 3D printed. These products offer the same functionality as traditionally manufactured prosthetics, but with a reduced wait time for patients.[258] The lower price of these products makes them particularly valuable for use with children, who quickly outgrow their prosthetic limbs.

Dental applications

3D printing can provide dental solutions with speed and accuracy, and at a lower cost. It is already being used to create customised braces, dental restorations, castable crowns, dental bridges, and denture frameworks and bases.[256] The wait time is significantly reduced as moulds are no longer needed, and the desired feature can be designed and printed directly for treatment.

Skin, human cartilage and tissue repair and reconstruction

Limb replacement and organ transplants are being successfully achieved through 3D printing, and bone and muscle repair has been made possible through the production of orthopaedic implants. As customised organ development uses the patient's own cells, transplant success rates are often improved.

Sterile surgical instruments and medicine

Precise 3D printed surgical instruments can be manufactured at lower costs than stainless steel tool equivalents. Tools can be quickly replaced and designed in unique shapes as needed.[256] One multidose could be printed for patients who have multiple chronic diseases.

Surgery models

Surgeons can practise complicated surgeries on patient-specific organ replicas generated through 3D printing, which show the patient's exact anatomy. Rehearsing is beneficial for surgeons as it helps them to anticipate what will happen during the procedure. 3D printed models and surgical guides are useful training materials and can be used to explain procedures to patients, reducing the trauma associated with complicated surgeries.[261]

PLATFORMS

Examples of how 3D bioprinting may be used are provided below.

PRECISION MEDICINE	INTEGRATED CARE
Prosthetic and orthotic devices will be customised to suit a patient's specific anatomy. Standard desktop 3D printers will use thermoplastic polymers as a base material, which can be infused with drugs and nanoparticles to create 3D printed multi-layer pills.[262] These have been successfully tested for patients with diabetes to help with medication dosage. For the patient, this eliminates exhaustive monitoring of drug intake when medications have different schedules. 3D printed drug delivery systems can also be extremely cost-effective, making them more accessible to patients.[256]	An increase in the production of 3D printed medicines and devices is likely to result in them becoming more locally available. Packaged medicines and prosthetics are likely to be replaced by digital files of designs, which hospitals and pharmacies can print when required using stored raw materials.[263] This distributed manufacturing will support equity of access for medicines and devices, albeit with a prerequisite for suitable printing technology and raw materials.

BARRIERS AND CHALLENGES

The deployment of bioprinting technology in Australia faces challenges associated with application, regulation and market access, and resources.

Application Healthcare professionals need to explore the opportunities offered by 3D printing to drive its successful application.[263] Bioprinting parts of the human body will take time and understanding, and will require the identification of suitable materials, software and hardware, and cell growth rates.

Regulation and market access Regulators need to define specifications to ensure that medical designs and 3D printers are used safely.[262] Bioprinted technologies need to pass safety tests and follow a proper regulatory process.

Resources While bioprinting in medicine has great potential, available industrial-grade printers and materials for advanced manufacturing technology are expensive, and a wider range of biocompatible materials is needed.[262]

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

Australia is well placed to contribute significantly in the field of bioprinting, buoyed by increasing demand for 3D printed biological products. Appropriate regulation to mitigate the risks generated by the distributed production of 3D printed medical products will be vital to transforming the use of this technology for medical purposes.

Major research projects are well underway at the ARC's Industrial Transformation Training Centre in Additive Biomanufacturing at the Queensland University of Technology's (QUT) Institute of Health and Biomedical Innovation, in collaboration with the University of Wollongong, RMIT, Deakin University and the University of Melbourne. Other QUT research has already broken new ground in the design and manufacture of 3D printers, based on the concept of melt electrospinning. This enables printing at a finer scale than previously achieved — down to 0.01 mm — which can be precisely tailored for a variety of biomedical applications such as heart valves, blood vessels, nerve guides and bone scaffolds.[264]

Spin-off company Gelomics develops and manufactures advanced bioinks that allow 3D printed cells and the fabrication of 3D models for cancer research. Other initiatives underway in Australia include:

- Heart stents made from new polymers that could dissolve in the artery (Melbourne Medical School and the Melbourne School of Engineering)
- Development of a 3D printed graft for surgical repair of the scapholunate interosseous wrist ligament (Griffith University, Orthocell, University of Western Australia and QUT)
- The BioPen, which uses 3D technology to print live cells to repair damage to cartilage, muscles, tendons and bone (University of Melbourne, St Vincent's Hospital Melbourne, University of Wollongong and Swinburne University of Technology)
- Organoids built using stem cells, which have the potential to be used to boost a failing organ inside a patient.[263]

3.3.4. Combination drug and device products

The United States FDA defines combination products as products composed of any combination of a drug, biologic or device.[265] Combination products often involve loading a medical device with a drug or biological products for delivery to the body. They can range from over-the-counter pharmaceutical products to surgical implants and precision medicines (Figure 8).

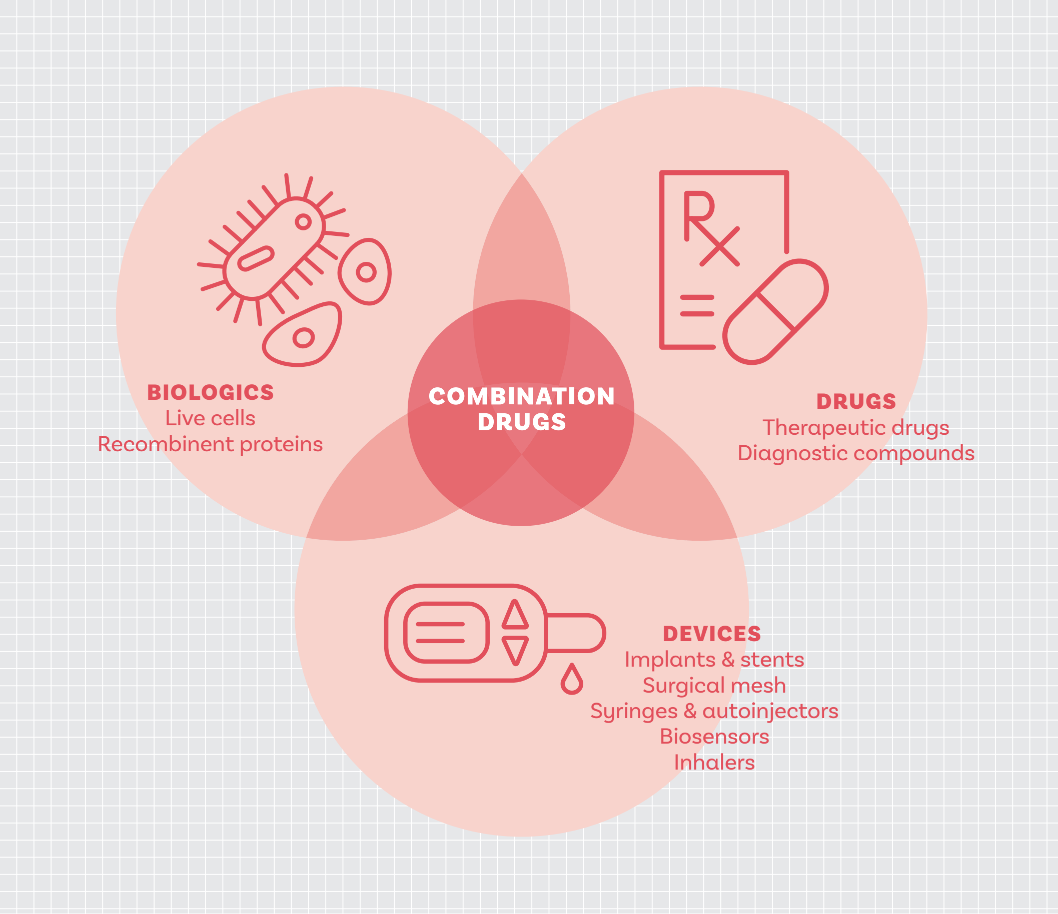


FIGURE 8
Schematic representation of combination products, which can be a combination of drugs, biologics and devices

APPLICATIONS

The applications for combination drug and device technologies are extensive. In particular, they have a role to play in preventing disease and maintaining general wellbeing by allowing individuals to manage their health without regularly visiting a healthcare professional. The use of combination drug and device products can allow rapid and ongoing treatment of chronic conditions by patients, without depending on primary medical assistance from GPs or hospitals.[266]

Commercially available combination products include asthma inhalers, epinephrine (adrenaline) auto-injectors, drug-eluting soft contact lenses, insulin delivery kits, contraceptive implants, microneedle patches, insulin delivery systems and nasal sprays. Combination products also include devices that monitor vital signs such as heart rate or blood pressure, or biological signals such as blood glucose, and respond to changing environments within the body to deliver drugs or biologicals. Such technologies are often part of the IoMT, offering network capability, remote control and real-time data collection.

Combination products that are used in more complex health interventions include surgical implants, drug-eluting stents, surgical mesh, personalised antibody/drug combinations, antimicrobial catheters or sutures, and antibiotic bone cement.

PLATFORMS

Examples of how combination drug and device technologies may be used are provided below.

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
Digital health apps will be used to monitor and control the delivery of drugs via eluting stents. Medical devices are increasingly used as digital health tools for the remote control of treatment and the monitoring of patient vitals.	Diagnostics and gene-testing kits will be used by clinicians at the point of care, and remotely by patients, for the purpose of genome sequencing and disease risk profiling.	As patients have greater ability to use combination products to manage their health and wellbeing, they may have better health outcomes.

BARRIERS AND CHALLENGES

The deployment and use of combination drugs and device technology in Australia face challenges associated with market access and regulation.

Market access The adoption of combination products by both healthcare professionals and patients will depend on accessibility, affordability, availability and willingness to pay (reimbursement). Equity (access according to need) and quality (adhering to international and national standards) will also need to be considered.[267] Stakeholder engagement will play an important role in commercial success.

Regulations A risk-management process should be followed during the development of devices to facilitate a structured and seamless regulation process. Information on device safety, hazards and efficacy, treatment duration, users (patient, caregiver or healthcare professional), and the frequency of doses should be recorded and presented for the regulation process.

EMERGING TECHNOLOGIES AND TEN-YEAR OUTLOOK

Combination products will support the growing integration of technology within medical products. With the increasing personalisation of medicine, technology that can capture, deliver or improve the efficacy of drugs or treatments will be essential. Future advancements in combination drug and device products may allow greater patient-centred approaches to health management, with patients able to self-medicate and manage their health and wellbeing with reduced clinical intervention.

> Ingestible sensors enable the targeted delivery of a drug to regions of the gastrointestinal tract. Researchers at the Massachusetts Institute of Technology (MIT) developed a 3D printed, wirelessly controlled, ingestible capsule to deliver drugs in response to smartphone commands. The Bluetooth-controlled capsule technology can sense the environmental conditions of the gut, transmit data and respond to smartphone commands for up to a month.[269]

Emerging health challenges (such as the rise in infectious and pandemic diseases, allergies and chronic health conditions) will prompt an increased dependence on combination products, such as vaccine delivery systems, drug-eluting implants, and personalised, at-home diagnostic kits. Technologies such as antimicrobial-coated medical implants and devices, used at the point of care, will improve patient treatment and recovery, and may help to combat the emergence of multi-drug-resistant bacteria.[268]

CHAPTER 4

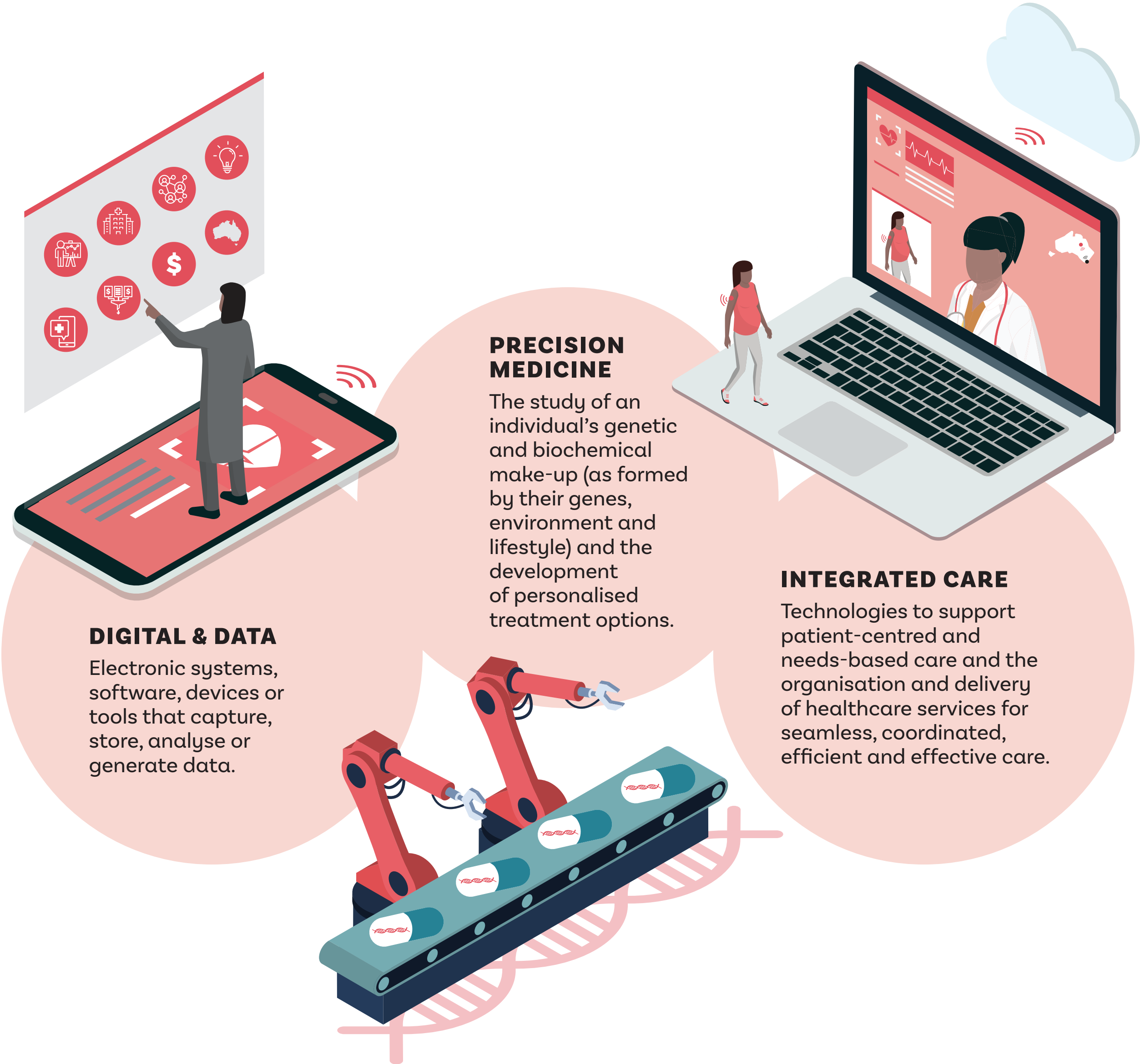
Potential solutions and sector technology readiness

CHAPTER 4

Potential solutions and sector technology readiness

The exponential rise in new technologies, discussed in chapter 3, has supported the development of platforms that will assist the Australian healthcare system to shift its focus to prevention and wellness.

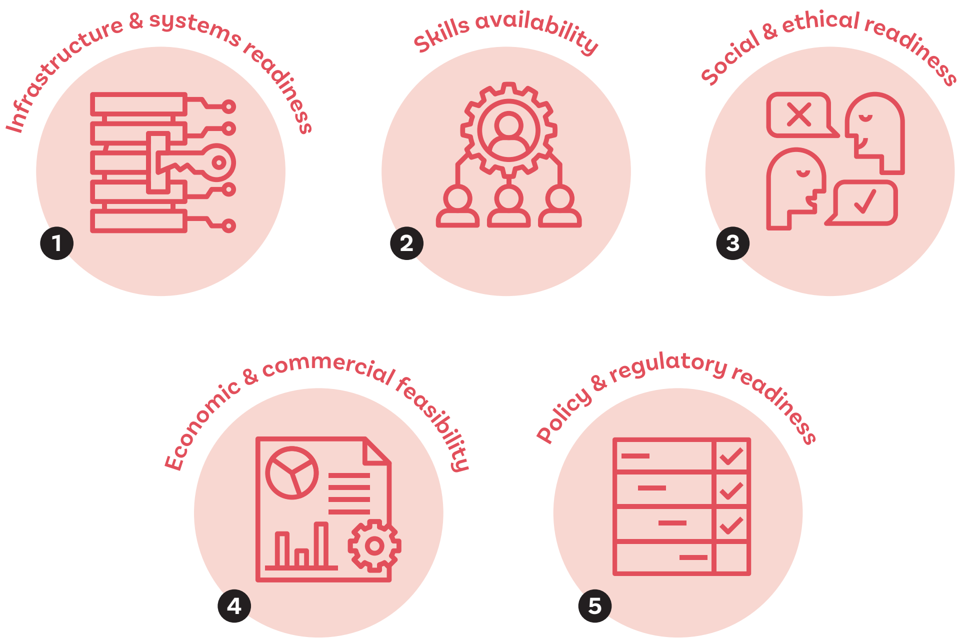
Based on their potential to improve quality of care over the next decade, ATSE has selected three of these technology-based solutions as key measures Australia could adopt, adapt or develop to address the challenges outlined in Chapter 2 in the decade to 2030.



In the decade to 2030, digital and data technologies will support the transition from paper files to secure electronic health records, from fax machines to interoperable health information platforms, and from fragmented health data to big data that can be analysed to accurately map and predict population health. Precision medicine will become more common, with prevention and treatment strategies targeted to individuals, and genetic testing an available and affordable option. Healthcare will become integrated through technology, with centralised electronic health records available (with patients' permission) to GPs, specialists, pharmacists and other healthcare professionals as its interoperability is expanded.

This chapter analyses each of the three identified potential solutions against five readiness parameters:

READINESS PARAMETERS



ATSE's analysis is based on desktop research, as well as consultations with stakeholders and experts. This chapter highlights the key aspects of these consultations and research for each potential solution, evaluated against the five readiness parameters. The results of the readiness assessments are presented at the end of each section. These 'outlook' assessments highlight strengths, weaknesses, opportunities and barriers that will affect the adoption, adaption or development of these technologies in Australia's healthcare sector by 2030.

CONSULTATIONS

This report was informed by research and consultations with healthcare stakeholders from across Australia, overseen by a Steering Committee and an Expert Working Group of Academy Fellows. These stakeholders included representatives from the healthcare sector and healthcare industry, policymakers and regulators, and research, not-for-profit, consumer and industry organisations and associations. ATSE consulted with over 230 stakeholders through dialogues, a survey, roundtable discussions and direct consultation.

Consultations began with a dialogue event held in Melbourne on 17 June 2019. Attendees included industry leaders, senior officials from the Australian and state and territory governments, senior research leaders and representatives from the not-for-profit sector. The dialogue focused on debate and discussion, with a view to identifying the technologies and innovations that will affect the sector, as well as key policy actions and research questions that should be addressed over the next decade.

Following the dialogue, a survey was opened to a wide range of healthcare stakeholders and other interested parties. The online survey captured a broad range of perspectives on Australia's technology readiness, with over 100 responses gathered. Stakeholders were asked to consider the readiness of Australia's healthcare sector to develop, adopt and adapt health-related technologies in the decade to 2030. Respondents were asked to rate the readiness – based on the five readiness parameters – of Australia's healthcare sector for the three potential technology solutions, on a scale of 0–4. This readiness scale is represented in Table 10.

SCALE	NOT READY	MORE WORK REQUIRED			READY
READINESS INDICATOR SCALE					

TABLE 10
Readiness indicator scale

Survey respondents were also asked to provide reasons for their ratings, and to key technology barriers and strengths, as well as policy and research opportunities to support the healthcare sector's technology readiness in the decade to 2030. The results of the survey were tested and augmented through a series of roundtable consultations in Melbourne, Canberra, Brisbane and Sydney, attended by a wide range of stakeholders from research, government and industry.

The purpose of this consultation was to understand the key factors that enable the uptake and integration of technology within the healthcare sector, and to highlight similarities and differences in the opinions of various stakeholders. The proportions of different sector participants consulted during the project are represented in Figure 9. In general, stakeholders expressed views consistent with the sector they represented.

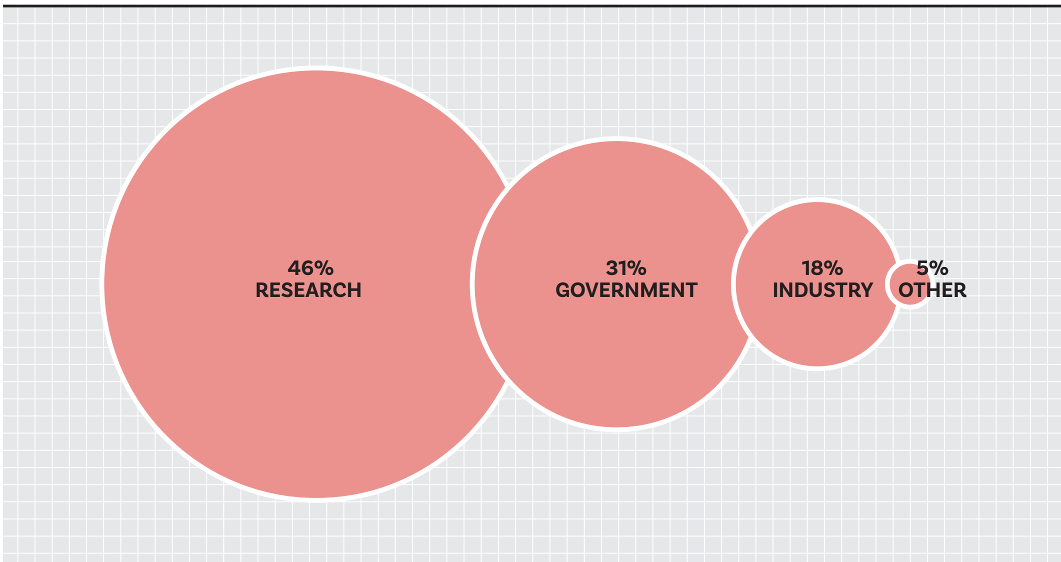


FIGURE 9
Proportion of sector participants during consultations

The research sector was strongly represented in the consultations, and many representatives from the research sector also had a background in clinical practice. The project did not hear wide perspectives from consumer groups and patients, which ATSE acknowledges would strengthen the findings. The consumer voice is particularly necessary when considering ethical, legal and social issues, and continuous consultations with consumers in implementing the potential solutions will reinforce trust in the healthcare system.

The results of the consultations were adjusted to reflect ATSE's research and analysis. A detailed record of the factors that informed the final readiness assessments can be found in Appendix A.

4.1. DIGITAL AND DATA TECHNOLOGIES

The digitisation and integration of healthcare data will be essential to improving clinical capabilities in prevention, detection and diagnosis, care coordination, treatment and rehabilitation, with improved population-wide health outcomes achieved through predictive technologies, decision support for healthcare providers, and increased patient access to health interventions.

The use of digital and data-driven technologies will allow greater response to chronic and emerging disease through the use of complex, intelligent technologies for disease prevention, early detection, diagnosis, treatment and monitoring. Data generated through the tracking, surveillance and analysis of population health will increase our capability to monitor trends in health and wellbeing, and to make predictions about the future of health, including challenges associated with threats from a changing climate and infectious diseases (emerging, remerging and persistent). Infectious disease genome data – produced from near-real-time, high-throughput screening – is already providing valuable insights into how infectious diseases are started, spread and evolved.[270] This data can also provide targeted approaches to infectious disease control at both the individual and population level.

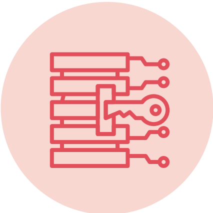
Data generated through the tracking, surveillance and analysis of population health will increase our capability to monitor trends in health and wellbeing, and to make predictions about the future of health

Decision-support technologies based on AI and machine learning will reduce clinical workload and offer significant practical benefits to healthcare professionals, as well as increasing patient engagement. Improved access to integrated healthcare data will allow the patient to own, manage and engage with their health information; and by using digital health services to increase people's access to health information, both healthcare professionals and consumers will be empowered.

Digital technologies will deliver significant economic gains in to Australia's healthcare system through faster, more efficient service delivery, and by analysing health data to improve system-wide resource management. Digital health services, including telehealth, apps and communications, will improve access to primary and specialist care and minimise regional and financial barriers. Australia is already moving towards digital technologies to deliver remote care and improve monitoring and data collection. Due to our geographic size and diverse population, Australia is an excellent testbed for new digital technologies – one of the seven strategic priorities of the National Digital Health Strategy. By 2022, six testbed projects will have been launched, with a focus on Health Care Homes for chronic disease management, babies' and children's health, telehealth and residential aged care.[53]

In the future, digital health technologies will become increasingly connected and interdependent to allow equity of access for all Australians. This will require the digitisation of health records and will rely heavily on affordable network and data storage infrastructure. Increasing volumes of sensitive health data will require proactive and adaptive cybersecurity approaches. Consumers will be the drivers of new health technologies and must be considered key stakeholders in their design, implementation and management.

ATSE's consultations confirmed that digital health technologies such as electronic health records, telehealth, wearable and implantable devices, and apps have the potential to revolutionise Australia's healthcare system by improving care coordination, improving access to primary and specialist care, and reducing or removing geographical and financial barriers. To achieve these benefits, the healthcare sector must address the challenges of integrating and applying digital and data technologies, including poor data and systems interoperability, the use of older technologies in tandem with newer technologies, a lack of secure communications options, increased volumes of data, and a lack of connectivity and compatibility between healthcare platforms and software.

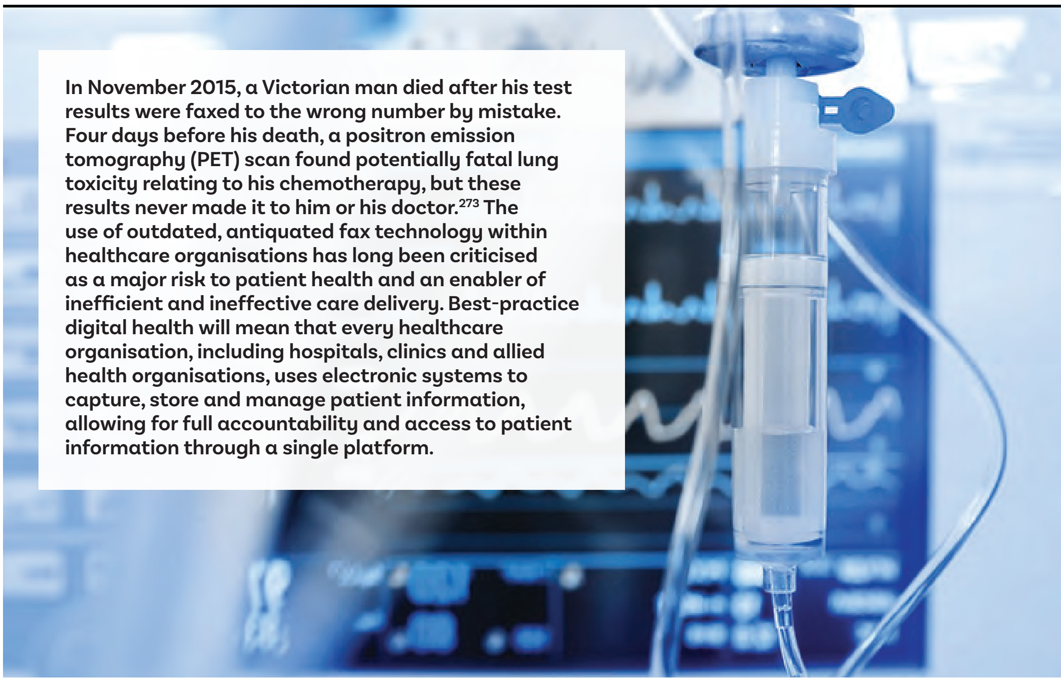


4.1.1. Infrastructure readiness

The predicted increase in uptake of digital and data health technologies by 2030 will necessitate a significant investment in infrastructure. Key infrastructure to support digital and data technologies includes tools for the collection, storage and management of health data (for example, electronic health records data, including My Health Record). Forty-six per cent of Australian healthcare providers already use digital tools to share electronic health records with other healthcare professionals, and a further 49 per cent would like to do so.[271]

My Health Record is a personal health record system that provides secure, online summaries of individuals' health information, to be used by healthcare providers and patients to store, access and share patient information securely (see page 48). As of 26 January 2020, around 90 per cent of GPs and public hospitals and 22.69 million consumers were registered to use My Health Record.[272] Registration by providers to access the MHR is increasing, but is lower for private hospitals, aged care, allied health, specialist organisations, and pathology and diagnostic imaging services. This clearly shows that while consumers are mostly ready for personal health records, some types of healthcare provider organisations have been slower to adopt them. These organisations must be supported to transition to electronic health records, including My Health Record, in order to realise the benefits of digital health for patients.

DIGITAL HEALTH = LIFE OR DEATH



In November 2015, a Victorian man died after his test results were faxed to the wrong number by mistake. Four days before his death, a positron emission tomography (PET) scan found potentially fatal lung toxicity relating to his chemotherapy, but these results never made it to him or his doctor.[273] The use of outdated, antiquated fax technology within healthcare organisations has long been criticised as a major risk to patient health and an enabler of inefficient and ineffective care delivery. Best-practice digital health will mean that every healthcare organisation, including hospitals, clinics and allied health organisations, uses electronic systems to capture, store and manage patient information, allowing for full accountability and access to patient information through a single platform.

In 2015, there were 1,414 digital hospitals in the United States, and only one in Australia.[274] As of 2019, the number of digital or 'smart' hospitals in Australia was growing, and smaller health organisations were transitioning towards digital systems. In a 2018 IQPC survey, 50 per cent of responding health organisations indicated that they were currently investing in new technology solutions, and that the technologies already making the biggest impact were healthcare portals (25 per cent), electronic medical records (22 per cent) and telehealth (20 per cent).[175]

An international approach to digitisation in health includes the Health Information and Management Systems Society's (HIMSS) Analytics Electronic Medical Record Adoption Model (EMRAM) for effective electronic medical records adoption, measured across eight stages of digital maturity (0 to 7). In 2018, two Australian hospitals achieved an international benchmark for electronic medical record capability by reaching stage seven maturity in the EMRAM framework, following their complete transition to paperless patient care.

Digital technologies, including wearables and apps, will increasingly rely on a seamless network connection. In Australia, the proportion of households without access to the internet at home remained constant between 2014–15 and 2016–17 at 14 per cent,[275] but there has been a significant increase in networked devices, with the number per household forecast to increase to 30 by 2021.[276] Improving network infrastructure will support the expansion of telehealth technologies, increasing the reach of Australia's healthcare system to those with limited access to healthcare services.

The NBN rollout is predicted to be completed by June 2020, with 10.3 million homes and businesses currently able to connect. Despite the improved speed and reliability of NBN-delivered internet, access to fixed-line connections may not be possible in certain remote and regional populations. (Currently, one third of Australia's population live in rural or remote locations.)[156] Australia's 5G network has recently launched in 290 locations across the country and may provide greater network access to certain regional areas. However, availability will depend on the replacement of existing network infrastructure such as antennas and mobile towers.[277]

As the volume of personal health data grows, the need for reliable, safe and versatile data storage will also become critical. Increasing use of IoMT-connected medical devices and wearables for data analytics purposes will require greater data storage capacity for hospitals and large-scale healthcare services, including on-premises data centres, cloud storage or hybrid systems. Most healthcare services prefer to use data centres, as on-premises data storage does not require a wireless network connection to retrieve files. However, upgrading and maintaining physical servers is both costly and time-consuming.[278] Cloud-based data storage offers scalability and interoperability with other systems, as well as a cost-effective approach to data migration.[279] Increasing use of healthcare cloud-computing is reflected in its rapid market growth, which is forecast to reach a value of $35 billion by 2022.[280] The 2019–20 budget allocation for the MRFF provided $80 million for data infrastructure.[281] Acquisition of aggregated, de-identified clinical data will facilitate improved research and translation of health technologies, particularly AI and machine learning tools, which require significant volumes of training data.

International cyberattacks have highlighted the need for comprehensive and strategic approaches to cybersecurity. In 2017, the WannaCry ransomware attack in the United Kingdom resulted in 19,000 medical appointment cancellations, and in 2018 a cyberattack on Singapore's healthcare services resulted in the theft of the health data of 15 million patients.[282] In Australia, all healthcare services are legally required to protect the privacy and security of personal health information, but the increasing frequency and severity of cyberthreats pose a significant threat to Australia's health information. The 2018 Health Informatics Society of Australia (HISA) survey of Australian health organisations found that 68 per cent of organisations have a documented cybersecurity procedure (up from just 44 per cent in 2017), and 60 per cent of respondents knew what procedure to follow in the face of a cybersecurity incident.[191] On average, 73 per cent of Australian healthcare providers have a formal governance plan that addresses the management of cybersecurity issues, but only 36 per cent perform an annual cybersecurity risk assessment.[283]

Improving digital accountability and cybersecurity standards is key to the safe integration of digital health tools. In recognition of this, the Australian Government is developing the 2020 Cyber Security Strategy to supersede its 2016 strategy. A recent audit conducted by the Auditor General's Office of the ADHA's implementation of My Health Record found that risks relating to privacy and IT systems infrastructure were largely well managed, but that management of shared cybersecurity risks (risks shared with third-party software vendors and healthcare organisations) required improvement.[282] The Agency has released a plan to implement recommendations of the Audit.

4.1.2. Skills availability

Current estimates suggest that more than 50 per cent of Australian workers will need to be able to use, configure or build digital systems in the next two to three years, and that more than 90 per cent of Australians will need to use some level of digital skills at work within the next five years.[284] As digital health technologies become increasingly integrated within the healthcare system, the type of skills required in the healthcare workforce will shift. The use of digital health technologies, as well as the capture, management and analysis of health data, will require a significant increase in digital skills in the medical workforce, including skills in using and interpreting AI, clinical informatics and health data analytics. It will also require an increase in the health information workforce, including those who are involved in developing, maintaining or governing systems for the management of health data.

Efforts to monitor the health information workforce in Australia include the Health Information Workforce routine census, conducted every three years by the University of Tasmania, the University of Melbourne, the ADHA, Australian Library and Information Association Health Libraries Australia, the Australasian College of Health Informatics, HISA, the Health Information Management Association of Australia, and the Victorian Government Department of Health and Human Services. The aim of the census is to delineate, count and quantify the Australian health information workforce in order to map the future workforce configuration, identify health information workforce shortfalls, and determine current health information career pathways and training opportunities.[285]

As the increase in health technology begins to yield increasingly volumes of health data, new roles will also be created and some existing roles will become more important. Roles that are likely to be increasingly in demand include health economists, clinical informaticians, data analysts, and doctors and healthcare professionals with a strong understanding of data science and digital technologies. With the growing volume of sensitive health data, there will also be a growing need for cybersecurity experts.

Developing a workforce with strong skills in applying digital health technology is one of the strategic priorities of the National Digital Health Strategy.[53] By 2022, the Agency will collaborate with governments, care providers and partners in workforce education to develop comprehensive proposals to provide all healthcare professionals with access to resources for training and upskilling in digital health, as well as a comprehensive set of resources and evidence to support and promote the use of digital health technology. The implementation of the National Digital Health Strategy is defined by the Framework for Action (2018), which provides a detailed timeline for the national rollout of training and educational programs for healthcare professionals to ensure digital health is embedded in training, national standards and accreditation requirements.[82] To promote cultural change in the industry, the ADHA will also establish a network of chief clinical information champions to promote awareness.

During consultations, stakeholders noted that Australia's health and medical workforce is highly qualified, and that there is a very strong research sector with excellent breadth and depth of talent in universities and research organisations. However, there is a lack of workforce technology readiness due to:

- Degrees in medical and healthcare disciplines lacking a strong focus on the applications and use of medical technologies or digital health and data (if these technologies are included at all)
- A lack of skills integration between medicine and data, engineering and software
- Difficulties creating collaborations between industry, research and the clinic

Medical and health-related degrees with strong foundations in health data and technology will be critical in ensuring that the future workforce has the skills necessary to work within an evolving digital and technical environment. The main area of employment for PhD graduates outside of academia is hospitals and healthcare,[286] with healthcare and social services employing 22 per cent of Australian PhD graduates.[287] A range of additional skills, including data capture, management and analysis, will be necessary as health technology develops and integrates into the healthcare system. Educational institutions, research bodies and governments will need to ensure that these skills are embedded into theoretical and clinical practice for vocational education and training (VET), undergraduate and clinical trainees.

JOB TYPES

Medical doctors, health economists, health informatics analysts, health analysts, digital health data or business analysts, biostatisticians, data scientists, biological scientists and researchers, systems engineers and cybersecurity experts

TYPES OF QUALIFICATIONS

Applied science, clinical informatics, clinical coding, cybersecurity, data science and analytics, engineering, health economics, imaging, IT, medicine, public health, healthcare administration, health informatics and software development

Medical and allied health professionals such as medical doctors, healthcare professionals, nurses, pathologists, epidemiologists, pharmacists and psychologists

Non-qualification-based training to upskill the existing workforce includes workplace training days, seminars, workshops, and training in digital tools such as virtual reality

TECHNICAL SKILLS REQUIRED

Medical or health expertise with skills in data science and technology, especially in machine learning; health and biological sciences; physics; engineering; IT; programming (Python, Java, R, C++); statistics and mathematics

Technical expertise with an understanding of healthcare and hospital logistics, health data systems and medical IT systems

Project management, R&D, data management and analysis, visual analytics, information systems, commercialisation and research translation

4.1.3. Social and ethical readiness

Australians are ready adopters of digital technologies and are willing to consider health digitisation. Over 80 per cent of Australians believe that digital technology will transform and improve healthcare, and 50 per cent want to access personal health information on their smart phone (although only 10 per cent currently do so).[288] Patients are also enthusiastic about new digital technology allowing them greater autonomy in managing their health.[289] Seventy per cent of Australians think healthcare providers could use digital technology and the internet to improve patient experience, and 58 per cent feel that sharing information is a key benefit of digital health technologies.[54]

A 2015 Deloitte report found that technology improved patient satisfaction and compliance in the United Kingdom, with 97 per cent of patients reporting high satisfaction and 94 per cent achieving better treatment compliance after using technology to manage or coordinate their care.[290] The Productivity Commission's review of integrated care found that 84 per cent of Australian doctors believe patients should have access to their electronic medical records, and 49 per cent believe patients should be able to edit or update their own information.[62]

ATSE's consultations confirmed that consumers and patients are ready to accept new technologies, but there are concerns surrounding data privacy, cybersecurity, data ownership, trust, and access and equity. There is also a lack of understanding around who owns the data, as well as low levels of health literacy among the Australian public. Engagement with and uptake of new technologies are heavily influenced by consumer trust, with 91 per cent of Australians rating privacy as a significant concern.[189] With 90 per cent participation rates in My Health Record, addressing privacy and data ownership will be a key priority for digital health authorities.

Encouraging the use of new technologies is also important. Despite the 90 per cent My Health Record participation rate, less than 8 per cent of people registered with My Health Record accessed their record via the national consumer portal in 2018–1989 and only 4 per cent have accessed their record more than once.[291] This low rate of utilisation indicates that patients and consumers are not yet engaging with their My Health Record directly and are instead relying on their healthcare providers to make use of their record. This highlights that social and digital literacy barriers to the direct use of My Health Record by consumers must be addressed. It should be noted that healthcare professionals are accessing consumers' My Health Records on their behalf when providing care, and that consumers have uploaded over 280,000 documents into the My Health Record system, such as advance care directives and personal notes.

Equity of access to digital health technology is also a barrier that requires further assessment. Cost and availability affect the uptake of digital technology by different populations, including remote and regional or socio-economically disadvantaged populations and Aboriginal and Torres Strait Islander peoples. Currently, 29 per cent of Australians live outside of major cities.[14] Despite the size of this non-metropolitan population, the number of healthcare services per capita for residents of remote regions is less than half of those in major cities,[292] highlighting the need for technologies that facilitate better access to care. Indeed, CSIRO[23] has identified empowering consumers and addressing health inequality as essential to Australia's health transition. Telehealth, transport improvements and communications infrastructures (such as the NBN and 5G networks) will help to improve equity of access for all Australians, including remote and rural communities, older people, people with disabilities, and culturally and linguistically diverse populations.

Healthcare providers are the primary users of many health technologies developed for clinical applications, but acceptance of digital technologies amongst clinicians and healthcare professionals is affected by perceived impediments to their ability to make independent diagnoses, and the impact on their relationship with patients.[289] More work is needed to shift the perception of data from a burden to a valuable tool. The healthcare workforce must be supported to make this transition, using the argument that data and digital technologies result in much better outcomes for patients. For example, one study found that changing from paper-based to electronic prescription ordering could result in an 85 per cent reduction in error rates, reducing a significant patient safety issue.[293] Better outcomes can be achieved by using data, integrating technologies, and providing information to patients in a way that will empower them to make decisions.

Consideration also needs to be given to how others can use health data, including for clinical and research purposes. The ethical implications of using health data for research must be further analysed, particularly with regard to the application of AI. In the 2018 Budget, the Australian Government allocated $29.9 million in funding for AI and machine learning, including the 2019 AI Technology Roadmap,[294] a standards framework and a national ethics framework.[101, 295]

Digital technology can also support patients' understanding of their own health. Sixty per cent of Australians have inadequate health literacy,[62] so educational tools and support will become increasingly important as people continue to gain increased access to personal health information through mHealth apps and online.

4.1.4. Economic and commercial feasibility

Digital technologies have the capacity to reduce the economic burden on the healthcare system by increasing automation, reducing workload and empowering patients to better manage their health and wellbeing. Australian hospitals are already using software developed by CSIRO to reduce hospital wait times and improve patient flow, allowing for a better quality of care.[296] The use of digital technologies for communication and data sharing in health will also yield significant economic benefits, with the introduction of secure messaging offering a gross economic benefit of $9 billion over ten years.[297] Through automation, increased connectivity and the use of advanced data analytics, Australia's healthcare expenditure could be reduced by up to 12 per cent per year.[298]

At present, Australians' health information is spread across many different paper-based and electronic systems, making it difficult for healthcare professionals to have the full picture of a patient's medical history. This lack of accurate medical information is partly responsible for the estimated 2 million adverse drug events in Australia every year,[299] approximately 10 per cent of which result in hospitalisations, costing taxpayers up to $1 billion annually.[300] PwC estimates that a full transition to electronic health records would require an investment of approximately $10.1 billion over ten years, but that it would bring an estimated economic benefit of $1.7 billion annually.[274] ATSE's consultations also found that interoperable data platforms would increase medical innovation and research.

Australia's health technology sector contributes significantly to our economy and will be affected by the growing digitisation of healthcare. The commercial implications of the digital evolution are that businesses will need to develop products with greater consideration for data standardisation, access, storage and security.[301] In terms of commercial feasibility, Australia faces some challenges relating to the commercialisation of digital health technologies. Australia has limited infrastructure to bring together the whole commercialisation ecosystem, which consists of universities, research institutes, start-ups, entrepreneurs, investors, and manufacturing or product development firms. This results in misaligned incentives and limits innovation.[61] Another major barrier is a lack of networks between industry, academia and health. Collaboration between researchers, industry and the primary healthcare system is necessary for the development of digital health technologies that align with the strategic and financial priorities of healthcare providers.[8]

SOFTWARE PLATFORMS

MEDICAL SOFTWARE INDUSTRY

Australia's medical software industry consists of start-ups and high-potential emerging software platforms, mostly developing electronic medical records. These include Telstra Health, Best Practice Software, Genie Software Solutions, MedicalDirector, MediRecords, HealthEngine and Healthshare.

Telstra Health is forecast to reach US$1billion in capitalisation – unicorn status.[302] The aim of the Telstra Health platform is to connect patients and healthcare professionals, government and health funds.

Software companies that offer secure messaging between healthcare professionals include Foxo, Personify Care and med-e-link.

4.1.5. Policy and regulatory readiness

Current efforts to support the digitisation of healthcare in Australia include the National Digital Health Strategy, approved by COAG in 2017. Developed by the ADHA, the strategy defines a set of priorities for transitioning to digital health in Australia, to be achieved by 2022. These priorities include a commitment to high-quality data, secure communications, and infrastructure and standards to support the interoperability of health data and information systems, as well as the rollout of My Health Record for health data management and communication, and a national health interoperability strategy and roadmap.[303]

The development of a national health interoperability strategy and roadmap is the key priority in the National Digital Health Strategy. According to the ADHA, interoperability holds the potential to bring patients' records together from a range of systems, and to provide access to information from disparate sources, giving consumers and providers greater visibility and enabling research and innovation.[303] Through the roadmap process, the ADHA aims to develop an agreed set of standards and actions towards improving data quality and the interoperability of Australia's digital healthcare systems. The ADHA roadmap will include agreement on base-level requirements for using digital technology in healthcare, and for the improvement of data quality and interoperability through the adoption of clinical terminologies, unique identifiers and data standards.[303] ATSE's consultations revealed that interoperability standards are a key concern among healthcare stakeholders.

Other key policy challenges associated with using digital and data technologies in healthcare include ethics, data privacy and cybersecurity. Data privacy is a significant impediment to integrating digital technologies into the health system, due to the volume of sensitive personal data captured and stored by these technologies. Over 69 per cent of Australians are more concerned about data privacy than they were five years ago,[304] and the integration of digital health technologies into Australia's healthcare system will require efforts to address data privacy, security and access issues.

The Department of Human Services (DHS) will adopt secure cloud requirements under the Digital Transformation Agency's Secure Cloud Strategy, which means that Australian software companies will be required to complete an accreditation and compliance process, including the ASD's Certified Cloud Services List Certification, and guarantee that all data will remain within Australian jurisdictions. This mandatory policy will apply to all third parties using DHS cloud services, such as Medicare and My Health Record.[305]

During ATSE's consultations, stakeholders observed that Australia's regulatory bodies ensure that health technologies in Australia are safe, and that work is already being undertaken to develop a more adaptive regulation system. However, concerns were raised about the standardisation of data in electronic health records, data access, and the potential for fast-moving technologies to outpace regulation and standardisation.

CSIRO's Data61 has undertaken work on anonymisation and encryption, which allows insights to be collected from data sets while maintaining the privacy of individuals.[306] Their de-Identification Decision-Making Framework can help data custodians identify and address the key factors relevant to their particular data sharing or release situation, including privacy risk analysis and control, stakeholder engagement, and impact management.

4.1.6. Ten-year outlook

The future of Australia's health system is digital. Through the adoption of paperless systems, electronic health records and digital communication platforms, and the increasing use of digital tools for care delivery, there will be reductions in clinical workloads and economic burden, greater efficiency in care delivery and improved health outcomes for Australians. However, there are a number of challenges that Australia must address in order to adopt data-driven and digital solutions in healthcare.

ATSE's research and consultations show that Australia's healthcare sector is not yet ready for data and digital technologies. We are somewhat prepared in terms of infrastructure readiness and economic and commercial feasibility, but have significant work to do in skills availability, social and ethical readiness, and policy and regulatory readiness (Table 11).

TABLE 11
Readiness indicators for data and digital technologies

ASSESSMENT					
	Infrastructure & systems readiness	**Skills availability**	**Social & ethical readiness**	**Economic & commercial feasibility**	**Policy & regulatory readiness**
Digital & data technologies	◑	◔	◔	◑	◔

ATSE's consultations and analysis found that Australia is at 50 per cent readiness in terms of infrastructure and systems for enabling digital and data technologies in healthcare, and that the main challenge will be integrating digital technologies into clinical settings. Integration and the effective use of these technologies will require a fast and stable network connection, appropriate data storage infrastructure, and a significant financial investment by healthcare organisations to overhaul old technologies and systems.

The National Digital Health Strategy aims to address several barriers with regards to data collection, sharing and interoperability, but stakeholders indicated that this may be more effective alongside a coordinated, national transition to electronic health records. Universally, stakeholders considered the digitisation of health records a foundation step in implementing data and digital technologies.

Stakeholders also indicated that research on the most effective methods of integrating new technologies into healthcare and clinical settings would be of value. As the volume of health data grows, it will be important to view data as a valuable resource, rather than a burden.

Australia must also address the skills gap in healthcare with regards to digital literacy. ATSE's consultations and analysis found that Australia is at 25 per cent readiness in terms of the skills that are available for digital and data technologies in healthcare. Stakeholders collectively reported that Australia will need to significantly improve digital literacy among medical and health graduates, and develop educational initiatives to provide data and digital training for the current workforce, in order to be ready for the impending digital transition in healthcare. Stakeholders highlighted the need to urgently review existing incentives to ensure that future skills requirements are met.

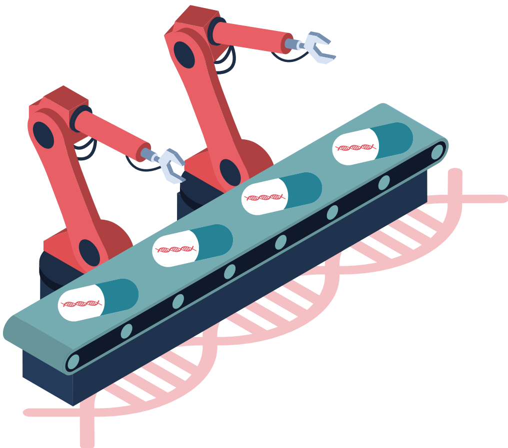
ATSE's consultations and analysis also found that Australia is at 25 per cent readiness in terms of social and ethical considerations for digital and data technologies in healthcare. Stakeholder consultations revealed that patients and consumers are ready to adopt digital health technologies, but that there are significant barriers impeding acceptance and uptake of such technologies including the privacy and security of health data, and equitable access to and benefits from these technologies. Data privacy is consistently rated as highly important to public confidence, and social willingness to adopt new technologies is influenced by the security of personal data.

Stakeholders noted that it will be important to build public confidence in new technologies in order to generate a social licence for their adoption and use. This can be achieved by establishing strong data privacy and protection systems. In terms of equity, health data must be representative of all populations in Australia in order to gain a full picture of the nation's health, and to provide equitable health solutions for those with poorer health outcomes, such as Aboriginal and Torres Strait Islander peoples, culturally and linguistically diverse populations, people with disabilities and economically disadvantaged groups.

It will also be important to address barriers associated with the commercialisation of data-driven health technologies. ATSE's consultations and analysis found that Australia is at 50 per cent readiness in terms of the economic and commercial feasibility of digital and data technologies in healthcare. Supporting science, technology, engineering and mathematics (STEM) start-ups and small and medium-sized enterprises to translate applied research will improve innovation capacity and support the domestic development of digital health technology. This support must include funding, infrastructure, agile regulations and strategic collaboration between government, industry and academia. Stakeholders agreed that Australia needs to reduce risk, provide more funding opportunities, highlight successes, reduce regulatory barriers, provide mentorship and support for start-ups, and create a push for more investment in health technology commercialisation.

Collaboration between researchers, industry and the primary healthcare system (hospitals, clinics and other primary healthcare providers) is critical for the development of digital health technologies that can meet the needs of the healthcare system and align with the strategic and financial priorities of healthcare providers. Exemplar models include CSIRO's collaborations with healthcare providers to develop a range of digital health technologies, such as a database for multilingual clinical terminology,[301] predictive software to identify patients at risk of readmission[307] and automated image analysis software for drug discovery.[308] During consultations, stakeholders noted that having the right data policy framework in place will shape the commercial landscape in which companies operate, providing an opportunity to improve commercial participation in this area of rapid technological growth.

In terms of policy and regulatory frameworks for digital and data technologies in healthcare, ATSE's consultations and analysis found that Australia is at 25 per cent readiness. This poor rating is driven by a number of factors from across the readiness indicators, taking into consideration the ten-year outlook for digital and data-driven technologies in the healthcare sector. It was noted that fast-moving technology advancements are outpacing Australia's regulatory environment, that data privacy is a significant barrier to the development and adoption of new digital technologies, and that there is a lack of interoperability and standardisation within the healthcare system, all of which is affecting the health of Australians and inhibiting innovation in the sector. ATSE acknowledges that the initiatives put forward by the National Digital Health Strategy will improve Australia's policy and regulatory readiness for data and digital technologies in healthcare.



4.2. PRECISION MEDICINE

Advancements in medical research continue to reveal relationships between disease, complex genetic factors and environmental factors. This creates opportunities for a new era of precision medicine — i.e. greater personalisation of medical treatment, tailored specifically to an individual. Precision medicines are not only new technologies; they may also change the ways in which we use existing technology in healthcare to make it more patient-centric.

Common precision medicine technologies include:

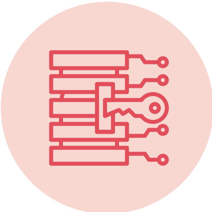
- **Genomics** Whole-genome sequencing, genetic testing, cancer genomics
- **Other omics technologies** Metabolomics, transcriptomics, proteomics, microbiomics, epigenetics
- **Gene editing and gene therapy techniques** For example, CRISPR-Cas9
- **Medical devices and implants** 3D printed prosthetics, bioprinted organs or tissues
- **Tailored therapies and products** Gene therapies, cell therapies, immunotherapies, 3D imaging, bioprinting
- **AI and digital health technologies** For example, risk-predicting algorithms, decision-making support software, health apps

Precision medicine has been identified as a potential solution for the transition to prevention and wellness as it supports a pre-emptive, predictive and personalised healthcare system and is a significant advancement in patient-centred care. With knowledge of genetic data, consumers will be empowered to make informed healthcare choices, and healthcare professionals can personalise care.

Precision medicine takes into account variation in genes, environment and lifestyle for individual people, relying on a combination of omics technologies and systems biology to develop targeted treatments or health interventions for disease. This technology is dependent on knowledge of individual genetic conditions that influence diseases, as well as adverse reactions to particular types of medications and metabolic pathways. It allows healthcare to be finely tailored to each individual, enabled by genomics, big data, data analysis and AI.[309]

The adoption of precision medicine technologies will help Australia to shift to tailored, person-centred healthcare interventions for prevention and wellness. By 2030, for example, genetic screening may be used for preventative purposes to improve health outcomes.[309] The use of population-based screening approaches has already demonstrated a significant reduction in cancer-based mortalities in Australia, with screen-detected cancers found to be less likely to cause death than cancers in unscreened patients.[310] Genomic screening approaches will be commonly used to detect cancer-related pathogenic variants, such as the BRCA1/BRCA2 cancer genes; and for carrier screening for muscular dystrophy, fragile X syndrome and cystic fibrosis.[311] Recent evidence from research conducted at Monash University shows that population screening could reduce gene variant-attributable cancers by up to 28 per cent, and cancer deaths by up to 31 per cent.[311] Immune cell therapy will become a more common and effective treatment for cancer, and increased R&D and commercialisation of high-value precision medicine products will result in a growing medical technology sector, including the expansion of the health and life sciences workforce for the development and clinical application of these technologies. By improving early diagnosis of disease, the sequencing of diseases and the profiling of disease risk, and by developing tailored medical treatments and interventions to prevent, cure or manage illness, Australia will have a healthier population overall.

While there has been rapid uptake of precision medicine, it faces major challenges in reimbursement, clinical utility, data connectivity, costs and equity of access for all Australians. While the cost of human genome sequencing has decreased, it remains unaffordable to many. This technology will have a greater impact if it is accessible to all Australians through increased market competition.



4.2.1. Infrastructure readiness

Australia must develop healthcare infrastructure that supports the multidisciplinary and interdisciplinary practice of precision medicine. This infrastructure includes collaborative networks to conduct research and implement clinical trials, and systems to ensure equitable access to precision medicines and technologies.[226]

One such network is Australian Genomics, an 80-partner national research network that brings together clinicians, researchers and diagnostic pathologists to provide evidence needed to integrate genomic medicine into Australian healthcare. One of its flagship projects involves collaborating with patient groups and the ADHA to integrate genomic information into My Health Record.

Australia also has a number of government-funded genomics initiatives, including:

- The Melbourne Genomics Health Alliance
- The Sydney Genomics Collaborative
- The Queensland Genomics Health Alliance
- CSIRO's Australian e-Health Research Centre and Data[61]

Nationally, Australia has a number of genome sequencing resources for research and clinical applications,[234] including:

- The Australian Genome Research Facility (Victoria)
- The Kinghorn Centre for Clinical Genomics (New South Wales)
- The Ramaciotti Centre for Genomics (New South Wales)
- The Australian Translational Genomics Centre (Queensland)

Computing and data storage infrastructure to support the storage, sharing and curation of sequence data is a major challenge facing Australia's healthcare system. Emerging technologies such as genomics, computational biology, and bioinformatics require significant computing power and secure data storage, and they currently rely heavily on data infrastructure with limited utility due to a lack of linkages to clinical software and information systems. The capture, storage, management and use of clinical omics data must be standardised and integrated with the digital health agenda, potentially through My Health Record.

In terms of infrastructure to establish a precision medicine industry in Australia, we may look to model international examples such as the Cell and Gene Therapy Catapult (United Kingdom), which supports researchers and companies in the area of cell and gene therapies, from research and early clinical development through to manufacturing, regulatory approval and market access. This type of infrastructure may provide necessary support to establish precision medicine as a new growth industry and support domestic innovation.

Through ATSE's consultations, stakeholders noted that Australia was well placed in terms of its readiness for precision medicine technologies, but that more data would need to be generated to provide evidence to support the clinical practices that patients choose.

Denmark has embarked on a national mission to build technological infrastructure to support population-wide genome mapping for its 6 million citizens. Denmark's National Genome Centre aims to collect and analyse large amounts of genomic and biological data to profile individuals and generate personalised, targeted treatments. This population-wide genomic analysis, along with other biological data, will help doctors understand complex genetic relationships with disease, and improve their potential to predict and treat disease. With a team of experts in supercomputing, IT architecture and software development, Denmark is set to use its new technological and institutional infrastructure to achieve better medical interventions with fewer side effects for patients.

4.2.2. Skills availability

As new precision medicine approaches become increasingly integrated into clinical environments at the point of care, there will be a growing need to improve the genomics literacy of the current and future workforce. Building a skilled, genomics-literate workforce is one of the key strategic priorities of the National Health Genomics Framework, which aims to undertake genomic workforce mapping to determine current capabilities.[312] The National Health Genomics Framework Implementation Plan outlines strategies to support tertiary education providers to integrate genomics into their curricula and engage with professional bodies to provide training and professional development in genomics.[233]

Australia has a small but growing clinical genetics specialty. We have an estimated workforce of 150 clinical geneticists, 97.8 per cent of whom are working clinically,[9] and 480 genetic counsellors, 45 per cent of whom are working in clinical roles.[313] Australia is also home to a number of comprehensive cancer centres, including the Murdoch Children's Research Centre, Australian Genomics, the Kinghorn Cancer Centre and the Garvan Institute for Medical Research, all of which employ a highly skilled medical research workforce and support national and international collaborative initiatives in precision medicine and genomics.

Clinical trials are a key feature of the regulatory process for new precision medicines, and Australia's strength in this area lies in our depth of clinical trial expertise. Australia has 37 clinical trial networks currently in operation, with an estimated workforce of 6,900 highly skilled staff involved in conducting over 1,000 clinical trials annually.[314] Despite our current strengths in the clinical trials sector, Australia will need to review workforce gaps to prepare for the increase in precision medicine technologies approaching early-phase testing.

JOB TYPES

Clinical specialist roles such as clinical and molecular geneticists, genetic counsellors, clinical chemists, clinical pathologists and genomic epidemiologists

Medical and allied health professionals such as medical doctors, healthcare professionals, nurses, pathologists pharmacy and psychologists

Scientific, professional and technical roles such as health informaticians, biostatisticians, genomics and computer scientists, biological scientists and researchers, systems engineers and cybersecurity experts

TYPES OF QUALIFICATIONS

Medicine, applied health, applied science, biological and life sciences, bioinformatics, genetics and genomics, clinical informatics, data science and analytics, engineering, IT, software development and cybersecurity

Non-qualification-based training to upskill the existing workforce includes workplace training days, seminars, workshops and online courses

TECHNICAL SKILLS REQUIRED

Medical or health expertise with skills in data science and technology, especially in the areas of genomics, gene editing technologies and precision medicine.

Technical expertise with an understanding of healthcare, genomics data banks and data repositories

4.2.3. Social and ethical readiness

Australians are ready adopters of new medical interventions. ATSE's consultations found that consumer awareness and expectations of healthcare are increasing, and that the patient is becoming more empowered. Consumers and patients will increasingly start to demand more detailed information, in a format that is convenient for them, so that they can make their own healthcare choices. However, due to the volume of information becoming available, there is a risk that consumers will receive incorrect information and become misinformed as a result.

Australians are also keen to use new technologies to assess their risk of disease. More than 65 per cent of Australians report that they would allow their doctor to perform genetic profiling to determine their disease risk, and 59 per cent would be happy for this data to be incorporated into their electronic medical record.[315] Currently, 700,000 genetic tests are performed annually in Australia, representing a 70 per cent increase in molecular testing within the past five years.[316] However, precision medicine technologies raise specific ethical concerns regarding the development and testing of novel gene editing and cell therapies, genomic data privacy and consent, and issues of equity. Research into the social and ethical implications of precision medicine is key to ensuring equity in these technologies, as well as gaining public support and trust.

More than 65 per cent of Australians report that they would allow their doctor to perform genetic profiling to determine their disease risk, and 59 per cent would be happy for this data to be incorporated into their electronic medical record.[345]

ATSE's consultations confirmed that while precision medicine technologies are generally accepted by society, access and equity issues will need to be addressed to improve Australia's readiness for these technologies. The Office of the Chief Scientist[309] has emphasised the need for governments to address equal access to precision medicines across all patient groups – specifically Aboriginal and Torres Strait Islander peoples, regional and rural populations, and individuals with a higher risk of diseases – in order to address the gaps of disadvantage in health. Although precision medicines are likely to improve health outcomes at the population level, the high cost of these treatments will limit access to these medicines among disadvantaged populations. The subsidisation of high-cost treatments will be a challenge for governments looking to address equity of access to precision medicines and technologies.

The donation of aggregated, de-identified data for research is critical to the development of improved digital and precision health technologies, but as the volume of genomic information grows, databanks will become increasingly linked and achieving data security will become increasingly challenging.[317] Currently, only 43 per cent of Australians would be willing to donate their de-identified genetic data to universities or research agencies for research purposes, and only 39 per cent would allow a digital app to analyse their data to profile their risk of disease.[315]

Many Australians report concerns regarding the use of genetic data by life insurance companies, which may use this information as the basis for decisions about insurance coverage. With the recent growth in next-generation sequencing and the volume of genomic data, there have been calls for protection against such discrimination, and for clarity over genomic data ownership and privacy.[318] In response, the Financial Services Council (the peak body for insurance companies, which sets standards and codes of conduct) has introduced a moratorium on the use of genetic information in life insurance policy applications, effective from 1 July 2019 to 30 June 2024.[319]

4.2.4. Economic and commercial feasibility

The global economic outlook for precision medicine is overwhelmingly positive, with the precision medicine market expected to grow by 11 per cent between 2017 and 2024.[320] By 2023, precision medicine is expected to have a global economic value of over $87 billion.[321] Australia is set to benefit significantly from having a skilled medical and life sciences sector, with strengths in clinical trials, research and manufacturing.

Australia has world-leading clinical trial infrastructure, based on a rapid clinical trial approval system and a highly skilled workforce. Every year over 1,000 new clinical trials are commenced, representing an estimated $1.1 billion in direct expenditure.[314] R&D tax incentives reduce clinical trial costs compared to our international counterparts, making early-phase clinical trials in Australia 60 per cent cheaper than in the United States, after tax incentives.[313] During ATSE's consultations, stakeholders indicated that clinical trials and early-phase studies in Australia are of high quality, however, it was noted that access and equity remain an issue, primarily due to cost.

Following recommendations from Innovation Science Australia and the ACOLA Horizon Scanning Report,[9] the National Health and Medical Industry Growth Plan will provide $500 million over ten years for a Genomics Health Futures Mission, which will offer grants up to $5 million for innovative genomics research projects, available over nine years from 2019. The Growth Plan further aims to provide a minimum of $206 million to support 130 new domestic clinical trials, with increasing support for international clinical trial collaboration ($42 million over five years).[322]

Increased funding for collaborative approaches to precision medicine must also extend beyond R&D to include the integration and trial of new technologies in hospitals and other clinical settings. Clinical trials conducted in Australia are largely funded by industry, accounting for approximately $930 million of the $1.1 billion spent on clinical trials annually (government provides more than $164 million annually through the National Health and Medical Research Council (NHMRC) and other programs).[323] Despite the cost of funding clinical trials, they offer a high return on investment: a joint report by the Australian Clinical Trials Alliance and the Australian Commission on Safety and Quality in Health Care found that for every $1 invested in clinical trials, $5 was returned.[324]

> Australia's pilot, population-based genomic screening project, the Australia Reproductive Genetic Carrier Screening Project, will begin in early 2020. The pilot screening project will screen 10,000 couples from Victoria, Western Australia and New South Wales for up to 700 X-linked and recessive genetic conditions.[325]

Advances in precision immunotherapy technologies are also likely to facilitate strong economic growth. For example, the global CAR-T therapy market is projected to increase at a compounding annual rate of 51 per cent between 2018 and 2030.[326] The United States FDA forecasts that by 2025, 10 to 20 gene therapy treatments will be added to the market every year,[327] driving increased demand for pharmaceutical and drug products. In 2017, the FDA approved more precision medicines and companion tests than any other year, three of which were the first gene therapies ever approved by the FDA. However, the cost of precision medicine can be prohibitive. One of the approved gene therapy drugs, Spark Therapeutics Luxturna™ for retinal dystrophy, has a list price of US$425,000 per dose, per eye, making it the most expensive drug in the United States.[253]

Australia's healthcare system is a mixed public and private system, primarily funded by government, with Medicare subsidisation covering most medically necessary services.[9] Precision medicines present a new challenge regarding evaluation, Medicare subsidisation and coverage by private health insurance, raising questions about which genetic testing services should be publicly funded. Children and young adults with acute lymphoblastic leukaemia are already receiving CAR-T therapy Kymriah® for free. As of January 2020, the government will be treating an additional 200 to 250 patients; without government funding, this treatment would cost each patient more than $500,000.328

In terms of costs and benefits, evidence suggests that the clinical utility of genomic testing actually reduces the cost of care in Australia, with Australian researchers finding that the use of genomic sequencing triples the diagnosis rate for one third of the cost per diagnosis.[329] Such evidence demonstrates the cost-effectiveness of replacing inefficient and expensive traditional clinical diagnostic tools with precision medicine technologies.

Despite a strong medical research sector, Australia has poor rates of research translation and commercialisation in health and medical technology. It also underperforms in commercialisation compared to international competitors. In 2018, Australia ranked eighth in the OECD for annual patent growth, and the number of patents granted in Australia fell by 25 per cent between 2017 and 2018.[330] The main barrier to commercialisation is the loss of ventures during early clinical development stages, referred to as the 'second valley of death'. Ventures at this stage often have difficulty gaining funding to undertake phase I and II clinical trials to collect data to support proposals to venture capital, biotech and industry corporations.[61] Australia has model funding systems for applied research but it suffers from a lack of commercialisation culture and expertise, low tolerance of risk, and poor domestic and international business investment.

Australia has an opportunity to strengthen the commercialisation environment and culture by addressing major barriers relating to procurement, investment and collaboration. For example, government procurement decisions can be used to increase incentives for innovation. There are strong international examples demonstrating the effectiveness of using procurement strategies to drive innovation, such as the Small Business Innovation Research programme in the United States and the Small Business Research Initiative in the United Kingdom.[331] There is evidence that current procurement policies have limited innovation in Australia, although the Business Research Innovation Initiative may improve performance in this area.[332]

In terms of industry and business investment, Australian governments must ensure an up-to-date, agile regulatory environment and frameworks to encourage investment in bringing products to market here.[333] This environment may be strengthened by clear government leadership in ensuring symmetry in information sharing and aligned objectives.

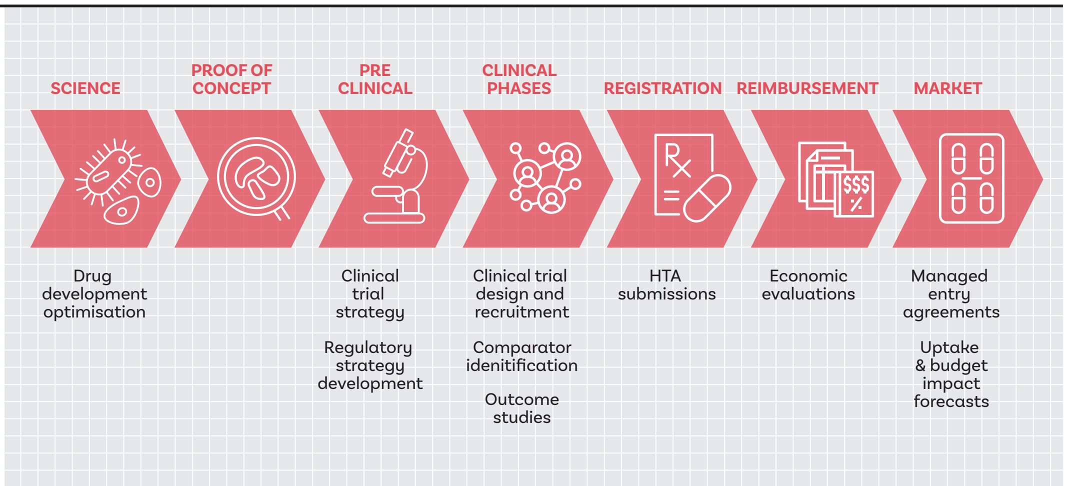
Australia has an opportunity to build an ecosystem of networks and connections that foster a culture of commercialisation through greater dynamic movement of expertise between academia and industry. This may alleviate the gap in commercialisation skills and expertise and improve intellectual property system engagement and understanding among researchers.[334]

4.2.5. Policy and regulatory readiness

The primary governing legislation for precision medicine in Australia is the *Therapeutic Goods Act 1989 (Cth),* administered by the TGA, which regulates the supply of medical products in Australia. The TGA monitors the safety, efficacy and quality of medical products by performing thorough pre-market assessments prior to providing market approval.

Despite having a well-established protocol for drug approval (Figure 10), the regulatory environment for precision medicines suffers from uncertainty relating to requirements and standards for new precision technologies. Determining statistical significance in the efficacy of precision medicines across a population is a particular challenge.[318] Regulators require robust evidence supporting the replacement of existing medicines with precision medicines, and clinical validation of new technologies is a challenge.[226]

FIGURE 10
Development pathway for a medicine or drug, reproduced from MTPConnect[8]



Despite the complexity surrounding regulatory approval of novel precision medicines, immunotherapies such as CAR-T therapy have made progress. The TGA approved Australia's first CAR-T therapy in December 2018 – Novartis' CAR-T product Kymriah® (tisagenlecleucel) – for the treatment of paediatric and young adults up to 25 years of age with B-cell precursor acute lymphoblastic leukaemia.[252]

There is a commitment to integrating precision medicine into the health system at all levels. In 2017, the COAG Health Council committed to the first National Health Genomics Policy Framework – a cross-jurisdictional plan to align national efforts to support the integration of genomics technologies into Australia's healthcare system. The implementation plan was approved by Health Ministers in November 2018 and aims to coordinate research and capabilities for disease prevention and early diagnosis, with a focus on delivering genomics technologies in an equitable and ethical way.

The framework identified five strategic priorities for implementation:

1. Delivering a person-centred approach to care
2. Developing a genomics-literate workforce
3. Guaranteeing sustainable and strategic investment in genomics
4. Ensuring safe and secure clinical use of genomics
5. Ensuring responsible collection, storage, use and management of genomic data

Australia also has a number of collaborative research initiatives examining regulatory mechanisms for emerging medical technologies in the precision medicine space. The HeLEX@Melbourne group was established in 2017 and works with the Oxford-based Centre for Health, Law and Emerging Technologies (HeLEX@Oxford) and Melbourne Law School's Health Law and Ethics Network to investigate legal and regulatory frameworks for new health technologies, including genomics and gene editing, cell therapies and digital health. The Centre for Law and Genetics (CLG) at the University of Tasmania focuses on the ethical, legal and social implications of gene technologies and engages in domestic and international collaborative research on innovative health and genomics technologies.

Stakeholders indicated that Australia has a good regulatory system, but that regulation and funding models are not entirely compatible with precision medicine, and that medical technology companies find it difficult to provide the type of evidence required for market approval. Specifically, it is difficult to determine statistical evidence of efficacy across a population for highly personalised therapies, which are tailored to individual pathologies or genetic conditions. Research has identified this as an important hurdle in Australia's legal and regulatory environment.[318]

Regulatory bodies in Australia aim to improve responsiveness to new health products and technologies, and in order to adapt to the rise in new and complex health products, the TGA has released its first Regulatory Science Strategy (2019). This strategy outlines plans to build and maintain regulatory science capabilities over the next five years in order to improve responsiveness to new technologies and collaboration with academic and industry stakeholders.

Policy and regulatory mechanisms for precision medicine must support the research and development of precision medicines and their integration into Australia's healthcare system. Precision medicine is a key objective of Australian governments, reflected in the increasing funding opportunities that are available through the MRFF, the Biomedical Translation Fund (BTF) and the Genomics Health Future Missions, and in the development of the National Genomics Framework.

4.2.6. Ten-year outlook

Australia is well positioned to benefit from advances in precision medicine over the coming decade. At the individual level, there is an opportunity to improve health outcomes, driven by an increase in genetic testing and advanced cell therapy interventions for cancer and rare diseases. At the population level, Australia could see a reduced burden of disease within the most disadvantaged populations, driven by providing greater access to detection and prevention technologies. However, before Australia is able to realise these benefits, a number of challenges must be addressed to improve Australia's capacity to adapt, develop and adopt precision medicine technologies.

ATSE's research and consultations show that the policy and regulatory framework for precision medicine is well developed in Australia, but the economic and commercial feasibility is currently poor. There is also some work required on infrastructure, skills and social readiness (Table 12).

TABLE 12
Readiness indicators for precision medicine

ASSESSMENT					
	Infrastructure & systems readiness	**Skills availability**	**Social & ethical readiness**	**Economic & commercial feasibility**	**Policy & regulatory readiness**
Digital & data technologies	◑	◑	◑	◔	◕

Australia is rated at 50 per cent readiness in terms of the infrastructure and systems needed for precision medicine. Australia boasts a strong R&D environment for precision medicine technologies and is producing world-class research in this area. However, infrastructure barriers include a lack of multidisciplinary and interdisciplinary networks to facilitate greater clinical trial capacity, and a lack of computational and data-storage infrastructure to support the storage, sharing and curation of sequencing data.

With regards to skills availability for precision medicine, ATSE's consultations and analysis found that Australia is also at 50 per cent readiness. Australia has a strong research workforce, but it will need to address the shortage of clinical genomics specialists and improve genomic literacy in the current medical workforce as these technologies become increasingly integrated into medical practice at the point of care. Clinical trial expertise will also become increasingly important over the coming decade following advances in precision medicine development.

Australians are willing to adopt new precision medicine technologies and are optimistic about the benefits of participating in genetic testing and disease profiling. ATSE's consultations and analysis found that Australia is at 50 per cent readiness in terms of social and ethical considerations for precision medicine. According to stakeholders, the main barrier to social and ethical readiness for precision medicine is the ethics of accessing these technologies. The high cost of precision medicine will also limit access by financially disadvantaged groups.

Australia rated 25 per cent readiness in terms of the economic and commercial feasibility of precision medicine, through ATSE's consultations and analysis. This poor rating is largely due to the notable commercialisation gap in Australia's medical sector. Australia loses a significant number of commercial ventures during early clinical development, when industry or venture capital investment is needed. Having the right regulatory environment to attract domestic and international investment is a major challenge facing the sector, and stakeholders indicated that this is an area most in need of policy support. Stakeholders suggested that research into effective policy and regulatory frameworks to promote research translation and commercialisation would be valuable, with consideration given to accessing investment and global supply chains, and improving collaboration between academia and industry.

Finally, with regards to policy and regulations for precision medicine, ATSE's consultations and analysis found that Australia is at 75 per cent readiness. The National Health Genomics Policy Framework is in place to guide national efforts towards integrating genomics technologies into Australia's healthcare system, and the approval of Australia's first CAR-T therapy in 2018 has laid the groundwork for greater development and clinical application of novel precision medicines. Stakeholders noted that it may be challenging to ensure that regulations keep pace with new medicines and technologies over the next decade.

4.3. INTEGRATED CARE TECHNOLOGIES

Most current healthcare interventions are focused on episodic pharmaceutical treatment and medical procedures.[62] For patients, it takes time and energy to navigate this fragmented healthcare system, which includes incompatible information systems and uncoordinated links between different healthcare professionals. This can become burdensome, particularly for patients living with chronic conditions, who must navigate appointments with siloed primary and secondary healthcare providers, either sequentially or consecutively, as either an inpatient or an outpatient. As a result, healthcare providers and patients experience uncoordinated, inconvenient and inaccessible care that is focused on their illness rather than their health. The likelihood of gaps is significant and can be dangerous.

A coordinated approach to patient health for the delivery of outcomes-based, patient-centred care will improve outcomes and empower both consumers and healthcare professionals. This coordinated, patient-centred model of healthcare delivery is known as integrated care. Integrated care is defined as the organisation and delivery of healthcare services to provide seamless, coordinated, efficient and effective care that responds to all of a person's health and social needs.[7] Integrated care is person-centred, with harmonised lifetime care delivered with dynamic efficiency to produce positive outcomes (Figure 11).[62] The integration of care will support the transition to a healthcare system that values and supports prevention and wellness.

The case for integrated care is clear: Australia has an ageing population with an increasing burden of chronic disease and a challenging population location profile, and current models of care urgently require greater coordination and a more patient-centred approach. Australians are experiencing increasingly complex care, with 15 per cent of people seeing three or more healthcare professionals for the same condition. This percentage increases with age, reaching 19 per cent among people aged 65 or older.[335] Among people who see three or more healthcare professionals for the same condition, 71 per cent report that at least one healthcare professional assists in coordinating their care.[335]

ATSE's vision for 2030, enabled by the adoption of integrated care technologies, is to begin the transition to patient-centred care in Australia. Electronic health records will be linked to a patient's

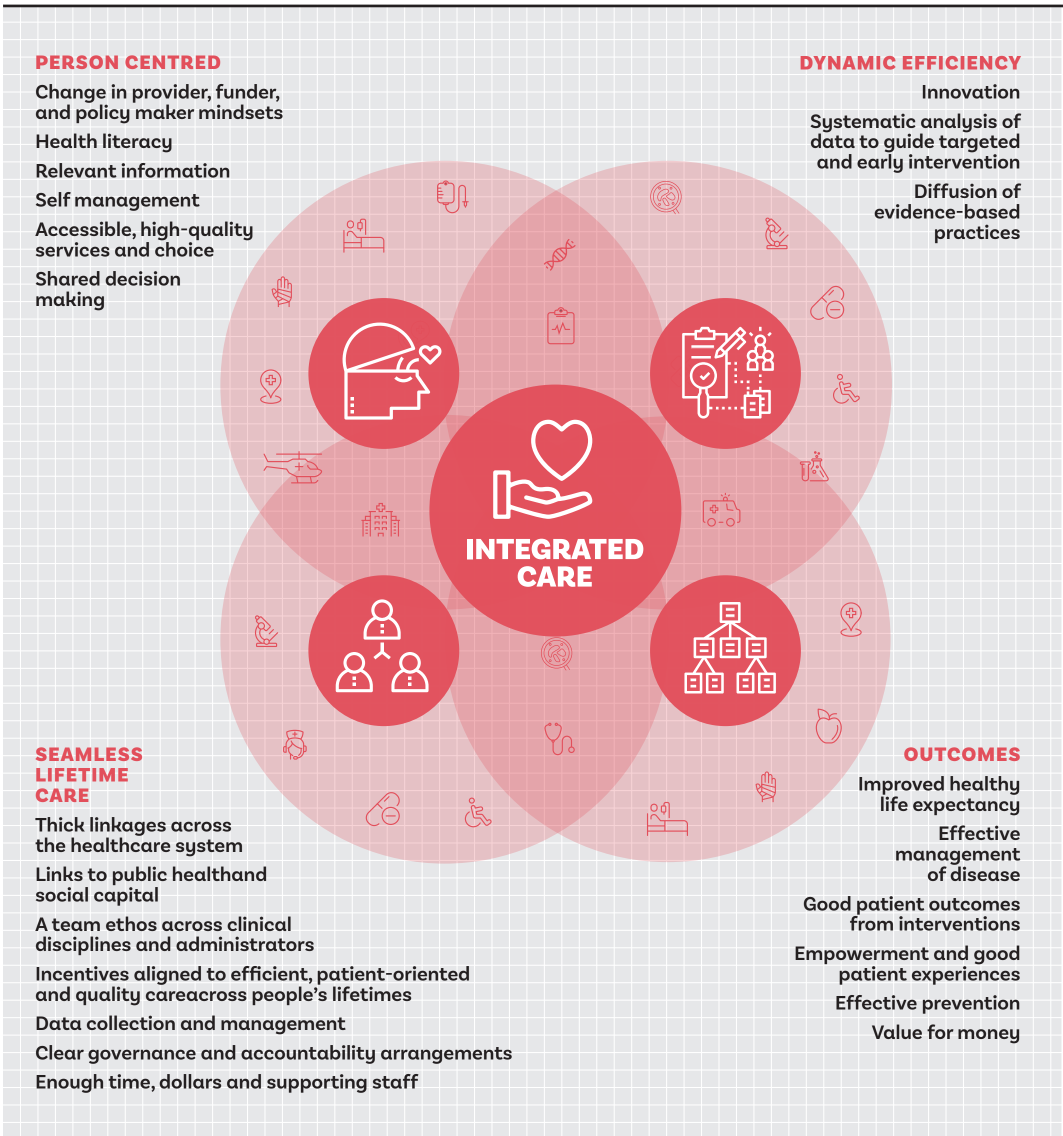


FIGURE 11
Essential elements of integrated care, reproduced from the Productivity Commission 2017 Report on Integrated Care[62]

GP, pharmacist and specialist, and with their permission, their healthcare professionals will be able to access their health information whenever they need it. Telehealth and mHealth technologies will improve healthcare access and outcomes for people in rural, regional and remote areas, people with disabilities, older people, and culturally and linguistically diverse communities. AI and mHealth will be used for scheduling, reminders and basic predictive functions, with a focus on prevention. Technology will be used to bring the healthcare system to the consumer, available when and where they need it, with all the information in one place.

For people with chronic diseases, there is evidence that integrated care improves the cost-effectiveness and quality of clinical care.[336] There are many other benefits of integrated care, including connected and easy-to-navigate healthcare and social care, better health outcomes for patients, improved healthcare system efficiency and greater workforce capability.[337]

Since 1995, an integrated system of patient-centred healthcare has been a policy objective in all Australian jurisdictions – a consensus embraced by COAG, consumer groups, businesses and health experts.[62] The Productivity Commission[62] recommends that an integrated, patient-centred system should give priority to the quality of services and their efficiency, embracing new technologies, preventative activities and social policies.

EXAMPLES OF INTEGRATED CARE MODELS IN AUSTRALIA

THE GOLD COAST INTEGRATED CARE MODEL

The Gold Coast Integrated Care Model was developed as a cost-effective solution to improve services provided to the local population with chronic and complex conditions.[338] At the heart of the model is a coordination centre, which is a legal entity of the Gold Coast Hospital and Health Services but is a designated off-site clinic. The centre manages clinical informatics, patient registers and referral networks (and will ultimately manage telehealth and remote monitoring capability) through the ICT system. The Gold Coast Integrated Care Model pilot trial ended in 2018, and the authors are currently determining economic and process perspectives of the model with a view to scaling up the program.[338]

WESTERN SYDNEY INTEGRATED CARE PROGRAM

An integrated care model for patients with chronic disease has reportedly been successful in integrating primary (community-based) and secondary (hospital-based) healthcare in Western Sydney.[339] Preliminary results include a reduction in the use of hospital services by people who have received integrated care services.[336] Several strategies, such as rapid access clinics and a patient hotline, were used in the program to manage health conditions, integrate care between service providers and develop shared-care protocols.[339] Improvements reported by GPs included better access to hospital specialist advice, delivered through telephone support. Health Pathways, a web-based platform, assisted GPs with the provision of evidence-based care,[339] although some found this platform challenging. Other reported challenges included a lack of IT-based communication, which limited the use of shared records. Hospital parking and transport were also identified as barriers to accessing hospital services.[339]

PATIENT-CENTRED MEDICAL HOME MODEL

The Patient-Centred Medical Home model delivers integrated care to manage acute and chronic conditions and support prevention and wellness, generally delivered through a general practice or Aboriginal Health Service.[340] Through the use of this model, care is coordinated by a diverse care team of GPs, allied health professionals and specialists, delivering an integrated approach to healthcare.[59]

4.3.1. Infrastructure readiness

Integrated care relies on seamless communication and data sharing between healthcare providers, patients and caregivers. Integrated care technologies will require interoperable systems for sharing electronic records, generating alerts and notifications, managing appointment bookings, delivering remote care and analysing health data.[341] Improving appointment booking systems technology also reduces the economic burden on clinics.[342] The integration of digital tools improves communication and care coordination and facilitates patient involvement in care delivery. The integration of interfacing tools and services provides for consistent patient advice and treatment, confirming the importance of data and digital technologies.

Recent research found that 61 per cent of healthcare providers feel that central systems and processes for patient lifecycle management are ineffective, and a further 58 per cent reported inefficient hospital-to-patient communication.[343] Digital infrastructure that supports healthcare providers to communicate and share data will be critical in supporting continuity of care, and in tracking an individual's journey through the healthcare system. An economic analysis conducted as part of the National Digital Health Strategy found that the economic benefit of secure messaging could be approximately $2 billion over four years, and as much as $9 billion over ten years.[53] By 2022, the ADHA has committed to delivering secure digital communication channels for healthcare professionals and patients, as well as a single online directory for clinical correspondence.[53]

The integration of standards-based remote care and telehealth platforms will also require high-speed, reliable network connections and funding for the development and supply of technology to patients and healthcare providers. In Australia, the 5G network will allow greater use of remote monitoring and telehealth technologies for real-time analytics, while also augmenting existing technologies by allowing machine-to-machine communications.[344] The ADHA has worked with the Northern Territory Government to improve telehealth services in regional and remote areas through the National Telehealth Connection Service. Results from the telehealth evaluation project found a significant reduction in travel, increased consult attendance rate, and estimated patient savings of over $1.1 million.[53]

Capital works and infrastructure upgrades are also needed for telehealth and other initiatives to improve health and wellbeing outcomes for Aboriginal and Torres Strait Islander people in rural and remote communities. Connectivity issues and the geographical reach of Integrated Allied Health Hubs to remote communities will need to be considered when implementing telehealth options as part of the face-to-face via-video model.

In 2015, the Australian Government established 31 Primary Health Networks (PHNs) – independent primary healthcare organisations located throughout Australia, funded at the regional level. Their main functions are to integrate healthcare services to improve the way the healthcare system functions at the local level; commission healthcare services to address the primary healthcare needs of their communities; and improve the efficiency, effectiveness and coordination of care.[345] PHNs work collaboratively with Local Hospital Networks (LHNs), which are public-sector bodies that manage hospitals and state government healthcare services in a given area. While alignment between these professional bodies is key to integrating healthcare services, the Productivity Commission has found that weak financial incentives and funding opportunities will act as barriers to PHNs achieving their goals.[62]

4.3.2. Skills availability

Integrated care requires the creation of multidisciplinary teams of healthcare professionals who are able to address the physical, psychological and social needs of the patient.[59] The implementation of integrated care technologies will require changes within the workforce and working environments, including new leadership and management roles (such as nurse-led care or case management) and new professional roles involving pharmacists, nursing staff and allied health professionals.[346] Medical professionals must also develop skills in teamwork, communication, coordination and data management.

While the adoption of digital technologies is key to delivering integrated, patient-centred care, a lack of organisational or technological capacity can act as a barrier to digital transformation. Adherence to data standards and data management protocols will improve care coordination, enabling all data to be collected, stored and managed in a systematic way, using interoperable platforms.

AI and machine learning technologies that improve automation of time-consuming tasks and provide decision-making support are predicted to reduce clinical workloads and improve patient experiences. Skills needed to develop and implement these technologies range from research skills to ICT and software skills. Undergoing organisational change to adopt and integrate new technologies will require support for the current workforce, including training, education and change management. Stakeholders observed that healthcare workers will require training to optimise the use of available technology.

JOB TYPES

Healthcare professionals, clinicians, GPs, health administrators, virtual care consultants and business operations officers

IT professionals, data scientists, software developers, systems architects, programmers, information security officers, governance experts, engineers

TYPES OF QUALIFICATIONS

Micro-credentials, workplace training, life-long learning, upskilling, personal development tools and programs

Postgraduate research degrees (PhD, master's), engineering degrees, business degrees

SKILLS REQUIRED

Digital health literacy, business operational experience, critical thinking, collaboration, communications, care coordination, public health, research and analysis, R&D, project management, teamwork, stakeholder engagement, interpersonal skills, commercialisation and research translation

Data management and analysis, systems analysis and design, cloud application development, business process modelling, software development, co-design, information systems, programming expertise (Python, Java, R, C++), visual analytics, an understanding of the Australian healthcare system

4.3.3. Social and ethical readiness

Patient experience is a central pillar of quality in healthcare and is positively linked to patient safety, clinical effectiveness, cost savings and reduced demand for healthcare services.[67] Currently, many patients experience poorly coordinated care from multiple healthcare providers through a fragmented network of healthcare professionals, health information platforms and appointment booking systems. This lack of integrated care can result in suboptimal health outcomes, duplication of medical tests, poor sharing of medical information, increased risk of harm and inadequate reconciliation of treatments.[347] The outcomes of poorly integrated care are worse for patients with chronic disease or complex conditions associated with low income or disability.[348] The adoption of integrated care technologies in order to align healthcare services with patient needs is therefore a key priority of individuals, governments and healthcare professionals as key stakeholders within the healthcare system.

Currently, 45 per cent of people report difficulty accessing healthcare when they need it, due to cost, location and appointment availability.[53] Access to healthcare professionals is a major issue for Australians living in regional and remote areas, who are six times more likely not to have a GP nearby than metropolitan residents.[292] Health inequalities for people living in remote and regional areas are partly driven by lack of access to healthcare services and specialist healthcare professionals. Integrated care technologies may improve access to care in regional and remote areas by removing physical and geographic barriers through the use of interfacing digital platforms, telehealth technologies, and improved coordination of care by primary care providers. The use of telehealth and remote monitoring technologies may also encourage better patient participation in healthcare, improve consult attendance rates and reduce economic strain. For example, research has found that improved continuity of care results in fewer visits to the emergency department,[349] reduced hospital admissions[350] and reduced medical costs.[351]

Face-to-face relationships with trusted healthcare professionals are vital to addressing service access barriers and telehealth is yet to be proven as an effective substitute for face-to-face clinical visits. It is important for its management and use in disadvantaged communities to be carefully considered.

ROYAL FLYING DOCTOR SERVICE AND ABORIGINAL COMMUNITY CONTROLLED HEALTH ORGANISATIONS

The Royal Flying Doctor Service (RFDS) of Australia works in collaboration with ACCHOs (Aboriginal Community Controlled Health Organisations) to provide specialist telehealth services to ACCHO clients living in remote communities. Telehealth consultations are booked by GPs and nursing staff, and, if required, nursing staff, can be present at the time of consultation to assist.

Regional hospitals often have limited access to new technologies due to funding limitations, geographic isolation, and transport and infrastructure limitations, as well as poor collaboration capacity with medical research institutes and universities to trial new technology. Technology replacement programs to identify, remove and replace outdated technology or inefficient systems may improve equity in healthcare access for regional and remote populations, improving the health gap between remote and metropolitan residents. The Victorian Government has initiated a Medical Equipment and Engineering Infrastructure Replacement Program to replace ageing medical equipment and upgrade engineering infrastructure in regional Victorian hospitals.[352]

Fundamentally, integrated care is a healthcare model that focuses on patient health rather than illness. Integrated care requires all members of a care team – including GPs, specialists, nurses, hospital staff, family members and carers – to work together to overcome the complexity of the healthcare system and achieve the best patient outcomes. Although this model relies on healthcare professionals to coordinate and deliver care, patients are the core drivers of this health model and integrated care technologies must be aligned with patient needs as the core priority.[353]

The challenge of communication between healthcare professionals has a direct impact on quality of care and patient health outcomes, often resulting in medication errors, which account for an estimated 20–30 per cent of hospital admissions for people over 65 years old.[300] Issues relating to communication are more likely to affect people living in regional or remote regions, where 18 per cent of residents report problems caused by a lack of communication between healthcare professionals, compared to 13 per cent of people living in major cities.[335]

During ATSE's consultations, stakeholders felt that integrated care technologies were generally accepted by society, and that consumers were willing to adopt these technologies. However, it was noted that access and equity issues will need to be addressed to improve Australia's readiness. Concerns were expressed that these technologies have the potential to be of most benefit to rural and regional populations, including Aboriginal and Torres Strait Islander peoples, but that funding models would likely hinder adoption in these communities.

4.3.4. Economic and commercial feasibility

There is evidence that integrated, patient-centred care can improve patient outcomes while decreasing the cost of care.[354, 355] Telehealth and digital health technologies offer opportunities for healthcare providers to deliver greater patient-centred care with reduced financial burden. The Productivity Commission estimates that the annual cost to patients of excessive waiting times for GP and specialist clinics may translate to a 0.1 per cent reduction in Australia's annual labour supply, with costs around $900 million.[62] Using telehealth for 10 per cent of consultations would save up to $300 million annually in travel and waiting times.[62]

However, stakeholders agreed that cost was the greatest barrier to adoption, as well as the integration of new IT systems and procedures. Hospitals also report the main barrier to digitisation as finance, with 53 per cent of health organisations reporting budget limitations as the biggest inhibitor of technology-driven, patient-centred care.[175] Australia's healthcare system operates under a series of budget silos, which is financially inefficient and inhibits progress towards integrated care. Most GPs are funded by the Medicare Benefits Scheme funding model, which does not offer financial incentives for healthcare professionals to avoid high-cost activity; make use of low-cost activity (such as phone consultations); limit future consultations; promote preventative health strategies; or engage in team-based care.[62] GPs have even been warned not to co-claim physical consults with mental healthcare.[356]

Funding models for integrated care should incentivise better patient outcomes, telephone consultations, team-based care approaches, and the adoption of digital health technologies.

4.3.5. Policy and regulatory readiness

The Australian health regulatory environment is becoming increasingly complex. There are more than 22,600 pages of combined state and federal legislation covering Australia's healthcare sector, and up to 100 combined Commonwealth and state regulators.[357] As Australia transitions to integrated care, the role of regulators will be to support the monitoring and registering of integrated care providers, and to evaluate the integration of connected systems and the quality of technology, particularly with regard to data privacy.

Misalignment between state and federal regulations around data sharing, communication and privacy currently hinders seamless coordinated care and the integration of assistive technologies. During ATSE's consultations, stakeholders highlighted that this misalignment also affects the rate of uptake of technologies. Asymmetrical data flows between states and territories, as well as between individual healthcare providers, result in reduced efficiency and poorer patient outcomes. The National Digital Health Agency's Framework for Action reports that state and territory governments will have responsibility for developing and implementing ICT, as well as collaborating with other jurisdictions to leverage cross-jurisdictional core ICT systems for the seamless sharing of health information.

In 2016, all states and territories signed bilateral agreements[358] to develop reforms to improve coordinated care in order to improve patient outcomes and reduce the burden on public hospital services. These reforms vary by state. The Victorian Integrated Care Model (Figure 12), for example, aims to reduce fragmentation of care by improving integrated service delivery between primary and acute care providers. This will be achieved by enhancing digital health capacity through:[337]

- Improving My Health Record connectivity
- Increasing digitisation of pathology and radiology reports
- Generating electronic referrals and discharge summaries
- Implementing a clinical information sharing platform
- Creating unique patient identifiers.

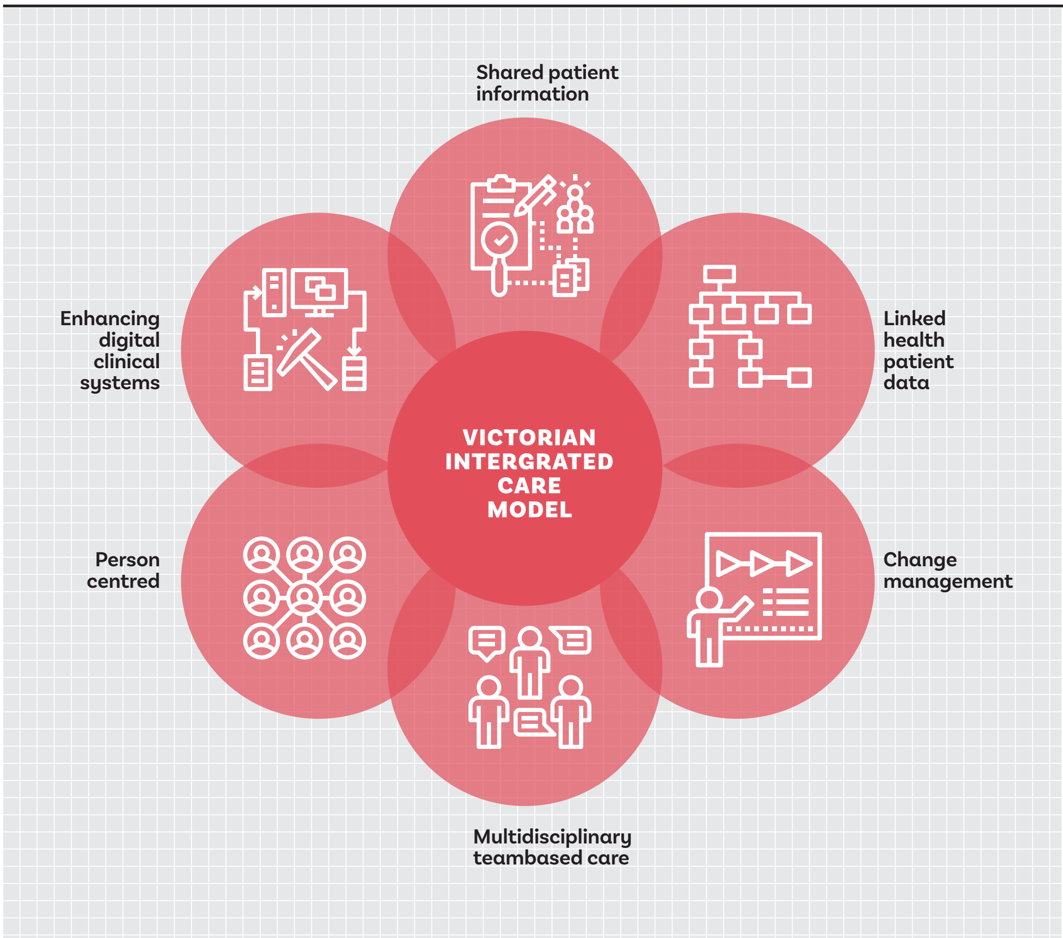


FIGURE 12
Victorian Integrated Care Model, reproduced from the Victorian Department of Health and Human Services (2019)[337]

4.3.6. Ten-year outlook

Adopting a coordinated approach to care delivery has the potential to improve the health and wellbeing of Australians and will improve resource efficiency within the healthcare system. The outlook for integrated care in Australia is positive, and there are already a number of initiatives working towards a more patient-centred healthcare system in Australia.

Australians increasingly expect their healthcare experience to be integrated, and social and ethical readiness for this model is high. Policy and regulatory readiness is hampered by lack of consistency between state and Federal regulation, but otherwise good. However, ATSE's analysis and consultations with stakeholders have highlighted a number of barriers to achieving integrated care, which include infrastructure and systems readiness, skills availability and economic and commercial feasibility (Table 13).

ASSESSMENT					
	Infrastructure & systems readiness	Skills availability	Social & ethical readiness	Economic & commercial feasibility	Policy & regulatory readiness
Digital & data technologies	◔	◔	◕	◔	◑

TABLE 13
Readiness indicators for integrated care technologies

In terms of infrastructure and systems readiness, ATSE's consultations and analysis generated a readiness rating of 25 per cent. This poor rating represents significant shortfalls in terms of systems, network and technological infrastructure. Most healthcare services operate on different software platforms, producing inconsistent and incompatible data that cannot be shared easily between healthcare providers, such as hospitals, GPs and specialists. The integration of interfacing tools and services will require significant investment, as well as a coordinated approach. Organisations must also develop adequate data security systems and controls in order to manage the increase in shared patient data and likely threats of cyberattack.

ATSE's consultations and analysis found that Australia is also at 25 per cent readiness in terms of skills availability for integrated care technologies. The skills gaps in digital health literacy, collaboration, data management, data analysis, communications and care coordination will function as major barriers to transitioning towards integrated care over the coming decade. Stakeholders indicated that they considered data literacy a major concern within the healthcare workforce, which must be addressed in order for the majority of healthcare providers to transition to new digital systems and processes. There is also a lack of cybersecurity training and awareness within healthcare organisations, which will pose a significant challenge as data sharing between healthcare organisations and professionals becomes standard practice.

Australia is at 75 per cent readiness in terms of social and ethical considerations regarding integrated care technologies. Consumers and patients increasingly expect integrated care, and the rise in complex health conditions will require a more coordinated approach to healthcare delivery. The major barrier to social and ethical readiness for integrated care is the professional culture in healthcare, which currently does not promote interdisciplinary and multidisciplinary teamwork.

Stakeholders also identified equitable access to patient platforms and interfacing technologies as an ethical challenge, as well as access to healthcare providers, especially specialists and metropolitan services. One opportunity for integrated care is to include the patient in care delivery; this may include the use of remote monitoring through wearables and implantable technology. Stakeholders identified determining the value of self-monitoring technology (such as wearables) in improving health outcomes as a research priority.

ATSE's consultations and analysis found that Australia is at 25 per cent readiness in terms of the economic and commercial feasibility of integrated care technologies. The major barriers are changing funding models in healthcare and shifting away from a budget silo approach, which prevent progress towards integrated care. The funding model for Australia's healthcare system is designed for the delivery of episodic care, rather than ongoing, coordinated care, and is therefore fundamentally misaligned in terms of achieving integrated care. Economic readiness will be a greater challenge for regional and remote healthcare providers, which are often underfunded and rely on older technology while coordinating care for patients between regional and metropolitan healthcare professionals. Stakeholders noted that research into the regional and financial factors that affect the uptake of new technology by healthcare providers would be valuable in order to address inequity in technology access for regional and remote communities.

Finally, with regards to policy and regulations for integrated care technologies, ATSE's consultations and analysis found that Australia is at 50 per cent readiness. The main challenge is the misalignment between state and federal policy initiatives in this space, which results in uncoordinated approaches and ineffective systems for communication and data sharing. Providing integrated care to all Australians will require a nationally coordinated approach.

4.4. SUMMARY AND CONCLUSIONS

ATSE's research and stakeholder consultations revealed a consistent and common theme: the current system of healthcare delivery is fragmented, inefficient and unsustainable. We must use technology to support a shift in focus to a patient-centred, outcomes-focused, value-based system of healthcare delivery. Supporting the healthcare sector to adopt, adapt or develop technology solutions will catalyse and accelerate this transition.

Overall, stakeholders indicated that significant work is already being done to improve Australia's technology readiness in the healthcare sector. However, we will need to work faster and with strategically co-ordinated effort over the next decade if we are to benefit from advances in digital technologies and data, precision medicine and integrated care technologies. The summary results of ATSE's full analysis are shown in Table 14.

TABLE 14
Readiness assessment

SCALE	NOT READY	MORE WORK REQUIRED			READY
READINESS INDICATOR SCALE	○	◔	◑	◕	●

ASSESSMENT					
	Infrastructure & systems readiness	Skills availability	Social & ethical readiness	Economic & commercial feasibility	Policy & regulatory readiness
Digital & data technologies	◑	◔	◔	◑	◔
Precision medicine	◑	◑	◑	◔	◕
Integrated care technologies	◔	◔	◕	◔	◑

As a nation of healthcare consumers, we are prepared for a technology-supported transition in healthcare – in fact, we expect it. Social readiness is high for all technologies except digital and data technologies, where readiness is limited by consumer concerns about cybersecurity. Consumer trust in digital health tools is fundamentally reliant on effective cybersecurity, and this must be addressed in the implementation of these technologies.

Policy and regulatory readiness for the transition is hotly debated by different parts of the sector, but most agree that it is heading in the right direction. Most stakeholders feel that the regulatory framework is supportive of precision medicine, and that while a policy change is needed to catalyse a change to integrated care technologies, the regulatory framework is appropriate. Policy and regulatory readiness for data and digital technologies was rated low, however, as there are so many critical areas yet to be addressed, such as interoperability standards, patient data ownership and privacy concerns, and the current system's inability to keep ahead of technological development.

To enable implementation of the potential technological solutions discussed in this report, Australia needs to provide significant support in infrastructure, workforce skills, and economic and commercial feasibility.

The infrastructure necessary for a healthcare system of the future is being readied, both physically and digitally, but this process needs to move faster. The proliferation of digital devices means that the system is being flooded with data, and developing the capability to analyse this data is critical.

The data is also fragmented and most systems cannot interact with each other, which means that we are losing valuable insights that could be used in precision medicine. Integrated care technologies are based on interoperable digital health records, requiring significant advances in infrastructure before the healthcare ecosystem can be connected.

Australia's healthcare and medical workforce is highly qualified, and we have a very strong medical research sector. However, a skilled workforce will be required to support the effective, informed and widespread implementation of health technologies. Daily use of digital health technologies, as well as the capture, management and analysis of health data, will require a significant increase in digital skills in the medical workforce, including in using and interpreting AI, clinical informatics and health data analytics; as well as an increase in the health information workforce, including those involved in developing, maintaining or governing systems for the management of health data. Stakeholders felt that medical degrees lack a strong focus on the applications and use of medical technologies or digital health and data, if these technologies are included at all. They also highlighted a lack of skills integration between medicine and data, engineering and software, as well as difficulties in creating collaborations between industry, research and the clinic. The workforce is also unprepared to use integrated care technologies, which require a multi-disciplinary, team-based approach.

Economic and commercial feasibility was rated low across all three potential solutions, primarily for two reasons. First, Australia's healthcare system is funded on the basis of episodic care; there are no incentives to do things more efficiently, with a focus on the convenience of the patient and their best health outcomes. New technologies remain expensive, and the healthcare system's resources are already overstretched. Issues with funding models are of particular concern to most stakeholders and underpin many of the challenges discussed in this report. ATSE has considered these issues in the context of evaluating the economic and commercial feasibility of the potential technology solutions identified in this report, but structural change will be needed to support the envisaged and necessary transition to a focus on prevention and wellness.

Second, despite generous government support, Australia's position as a world leader in health technology research is at odds with its poor translation and commercialisation record, indicating a system failure. Stakeholders noted that while Australia excels in R&D in the healthcare sector, the commercialisation of this research is often difficult. Australia has limited infrastructure to bring together the whole commercialisation ecosystem, which consists of universities, research institutes, start-ups, entrepreneurs, investors, and manufacturing or product development firms. This results in misaligned incentives and limits research translation and commercialisation. Small and medium-sized MedTech and pharmaceutical enterprises and start-ups face additional challenges in scaling up, including strong international competition and limited incentives for domestic manufacturing of medical devices and products. Incentivising commercialisation, providing mentorship for start-ups, and facilitating greater engagement by the healthcare system and research and industry sectors would actively assist the growth of Australian start-ups, rather than forcing them to go offshore. While Australia's health technology reimbursement arrangements were agreed to be in line with global best practice, it was noted that opportunities for co-investment are not actively encouraged.

In order to address these issues, and for Australia to be ready for the opportunities presented by each technological solution, ATSE has developed a set of robust, forward-thinking and achievable recommendations for stakeholders in government, industry and research. With these recommendations, ATSE hopes to position Australia to adopt, adapt and develop health technology to improve health outcomes for all Australians by 2030.

CHAPTER 5

Levers for change

CHAPTER 5

Levers for change

Australia needs a new prescription for healthcare – specifically, a focus on prevention and wellness, enabled by technology. To help meet this challenge, ATSE has drawn on expertise from across the nation to prepare a map for change.

Based on ATSE's analysis, the healthcare sector will need support in infrastructure, skills and the commercial feasibility of new technology if it is to use technology to make this transition by 2030.

The recommendations in this chapter aim to catalyse positive change and use technology to revolutionise Australian healthcare over the coming decade, grouped under four key headings. We encourage government, funding agencies, the healthcare sector, and the research community to use these recommendations as guidelines which will support them to meet the needs and expectations of diverse Australian communities, and work towards an effective and equitable, prevention-focused future healthcare system.

Four key issues emerged during ATSE's research and consultations:

1

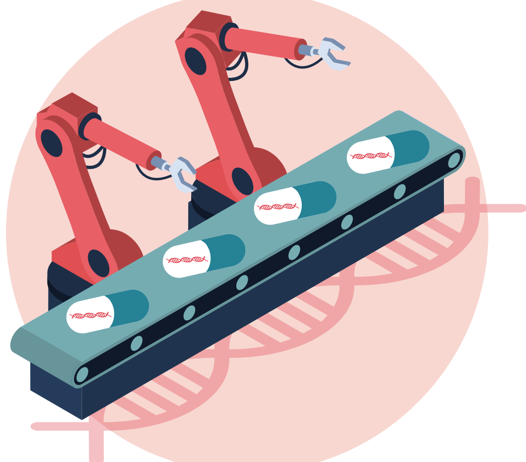
Digitisation of healthcare

2

Equity of access to healthcare

3

Workforce capability



4

Commercialisation of Medtech research

The most critical priority is the digitisation of health records – an issue that was highlighted by the majority of stakeholders and underpins the technology solutions identified by ATSE. Without a shift to electronic records, the fragmented healthcare system will not cope with increased volumes of data and the emergence of digital technologies, nor with the increasing personalisation of healthcare. Integrated care will be unachievable without electronic health records, which are essential for efficient, accurate, timely and patient-centred care.

Embracing new technologies will be vital in ensuring that the benefits of a wellness system are available in regional areas and Aboriginal and Torres Strait Islander communities, and to disadvantaged people in urban communities. Barriers to equitable outcomes include distance, communication difficulties, financial resources, education levels, accessibility, and shortages of healthcare workers. Mobile and telehealth services can easily and inexpensively help Australians overcome these obstacles and access the best available care in a timely way.

Empowering the workforce to maximise the benefits from new healthcare, data and communications technologies will result in increased efficiency, better decision-making and improved outcomes. The workforce must be supported in its transition to a focus on prevention and wellness, particularly developing skills to adapt to a technology-driven workplace.

Finally, the research sector needs a boost to provide the healthcare system with the tools it needs and ensure a robust return on investment. Despite generous government support, Australia's position as a world leader in health technology research is at odds with its poor translation and commercialisation record. Government has a responsibility to ensure that there is support for – and a clear path to develop – timely, cost-effective and commercially successful products from initial research outcomes.

ATSE has developed four recommendations to address these issues, outlined in this chapter along with supporting recommendations and research priorities. These recommendations were developed through analysis of stakeholder-nominated policy and research priorities, in the context of ATSE's sector research. They were thoroughly tested with relevant senior stakeholders in government, industry and research, and endorsed by the project expert working group and steering committee as robust, forward-thinking and achievable.

These recommendations are intended as priorities for government, funding agencies, the healthcare sector itself and the research community to help them meet the healthcare needs and expectations of diverse Australian communities, and to build practical research agendas to address questions about our future healthcare system. Australia is a global leader in health, but it is critical that we continue to identify what we want for our society, and for a healthcare sector of the future.

ISSUE 1

Digitisation of healthcare

There is a critical need to digitise healthcare. This process has already begun but is impeded by resistance to change in the healthcare sector and significant consumer mistrust. Stakeholders identified the digitisation of health records as the most important priority as this underpins all of the technology solutions identified by ATSE.

Without a shift to electronic health records, the fragmented healthcare system will not cope with the rise of data and digital technologies and the increasing personalisation of healthcare. Digital data capture, interoperable healthcare systems, safe and secure patient information sharing and readily available patient information depend on electronic health records, and will deliver improved outcomes for patients and clinicians by providing a holistic view of the patient's health, supporting decision-making and tracking outcomes.

PwC has estimated that while a full transition to electronic health records would require an investment of approximately $10.1 billion over ten years, it would bring an estimated economic benefit of $1.7 billion annually[274] in public acute hospitals and private hospitals. When extrapolated to primary care, the benefit will far exceed this. Accelerating the transition to electronic health records, enabling their interoperability and security, and building public trust in their use must be the highest priority for the healthcare sector.

Consumer trust in digital health is reliant on effective cybersecurity, so this transition to electronic health records will fundamentally depend on strong, well-communicated privacy and security frameworks.

RECOMMENDATION 1

Transition to interoperable electronic health records.

All healthcare providers must switch to electronic records as soon as possible. Social licence for this move will fundamentally depend on well-communicated privacy and cybersecurity frameworks.

To underpin this transition, ATSE makes the following recommendations.

RECOMMENDATION 1.1
Conversion to electronic health records should be mandatory for all healthcare providers in Australia.

To support this shift:

a. The Australian Government should lead the development of interoperability standards for digital health. These should include data collection, sharing and security standards, building on work conducted by the Australian Digital Health Agency (ADHA) to implement the National Digital Health Strategy deliverables on interoperability and secure messaging.
b. A public campaign should be launched to improve take-up and awareness of electronic health records, developed in consultation with stakeholders within the healthcare sector, and including patient perspectives.
c. Patients should retain the choice to opt out of having their information shared to a personal health record, such as My Health Record.

RECOMMENDATION 1.2
To build social licence, the Australian Government should develop a national framework to strengthen health data privacy and usage, building on experience managing health privacy under the *Privacy Act 1988*, and in response to the Productivity Commission's Inquiry into Data Availability and Use.

The framework should include:

a. Centralised, easily available information about existing rights and regulations, including in the information-sharing mechanisms between third parties
b. Clarity around people's rights to control, correct and determine access to their own health data, and that of dependents
c. Authorisation for aggregated, anonymised clinical and laboratory data to be available for research quality control and benchmarking

Australians are ready adopters of new technology, but there is limited research on best-practice integration of new technologies into healthcare. During the course of ATSE's analysis, other research gaps were identified, including research on how to gain public confidence in digital health technologies, and how to position health data as a valuable resource.

Stakeholders identified the integration of new technologies into the healthcare system as a challenge, highlighting that the cost, feasibility and value of new technology must be considered. As digital tools become increasingly sophisticated, stakeholders felt that ensuring the smooth integration of technologies into the workflow should be a priority. Stakeholders also agreed that social acceptance and patient engagement with technology is of high importance to gain public trust.

The following research priorities are designed to generate solutions for integrating digital tools into Australia's healthcare system. The integration of new technologies into an existing system requires a strategic approach, taking into consideration existing data systems and processes, data privacy and security, and future scanning for potential applications of health data for research.

In order to address the barriers to integration of digital health technologies in Australia, ATSE proposes the following research priorities for data scientists with knowledge or expertise in data management systems, health information systems and data privacy, and social scientists with interest or expertise in social acceptance of technology.

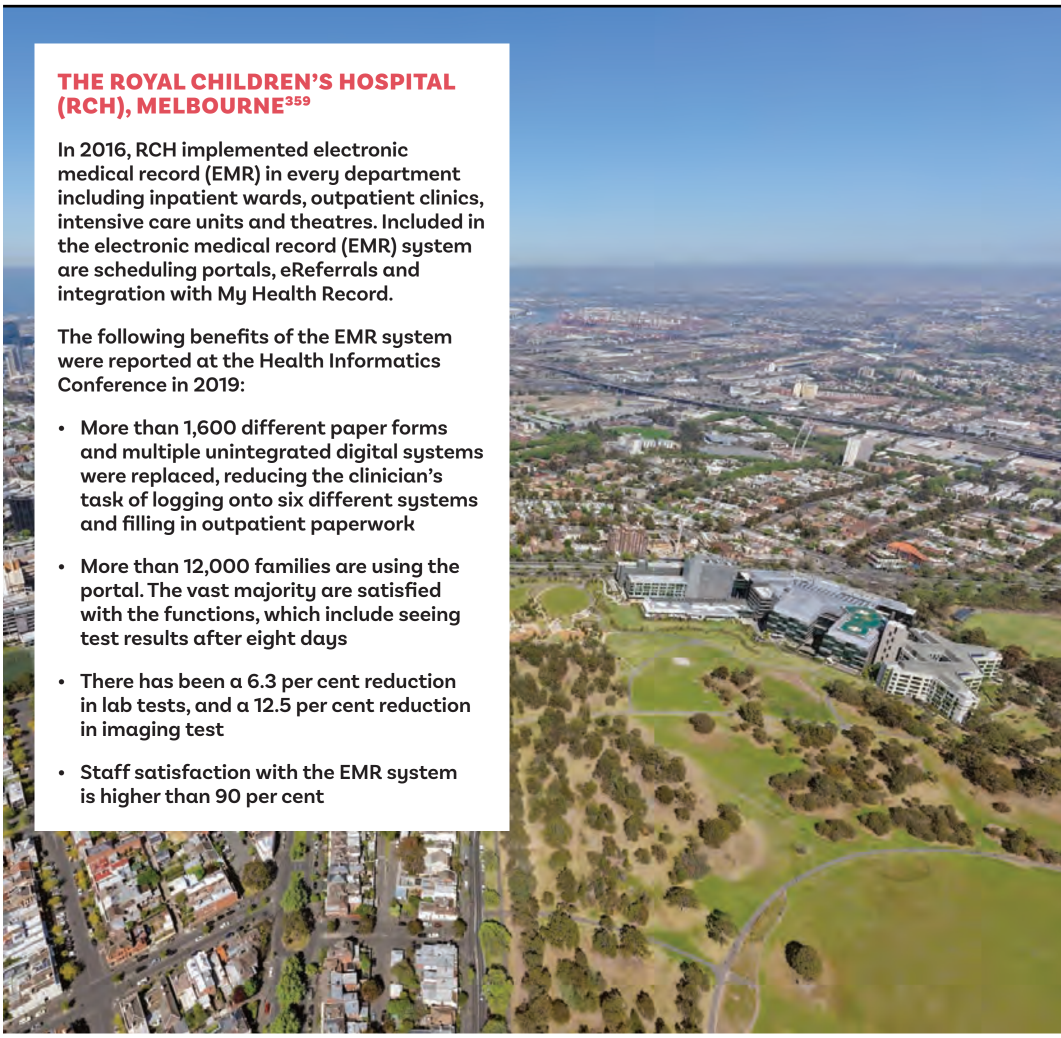
RESEARCH PRIORITIES

Research priority 1.1
How can existing and new technologies be integrated within different health settings or contexts? How do we 'join up' the health data ecosystem?

Research priority 1.2
How can we best build public confidence in digital health technologies?

Research priority 1.3
How can we shift perspective to value data, rather than regarding it as a burden?

ELECTRONIC MEDICAL RECORDS



THE ROYAL CHILDREN'S HOSPITAL (RCH), MELBOURNE[359]

In 2016, RCH implemented electronic medical record (EMR) in every department including inpatient wards, outpatient clinics, intensive care units and theatres. Included in the electronic medical record (EMR) system are scheduling portals, eReferrals and integration with My Health Record.

The following benefits of the EMR system were reported at the Health Informatics Conference in 2019:

- More than 1,600 different paper forms and multiple unintegrated digital systems were replaced, reducing the clinician's task of logging onto six different systems and filling in outpatient paperwork
- More than 12,000 families are using the portal. The vast majority are satisfied with the functions, which include seeing test results after eight days
- There has been a 6.3 per cent reduction in lab tests, and a 12.5 per cent reduction in imaging test
- Staff satisfaction with the EMR system is higher than 90 per cent

ISSUE 2

Equity of access to healthcare

Australia has a problem with equity in accessing healthcare, particularly with regard to new technologies, which can be expensive and restricted to urban facilities. Remote health technologies such as mHealth, telehealth and smart medical devices offer an inexpensive and flexibly accessible way of overcoming barriers of distance, communication, cost, mobility and shortages of healthcare workers.

A healthier Australian population will require technological solutions to these equity challenges, including the prevalence of sub-standard access to healthcare in remote, regional, and Aboriginal and Torres Strait Islander communities. Access to healthcare does not require expensive technologies; linked to a digital health system and an integrated care model, inexpensive point-of-care and self-testing can actually reduce costs and improve access for disadvantaged sections of the community. We need to expand mobile and telehealth applications and focus on integrated care to improve access to healthcare and reduce the financial burden.

Using telehealth for 10 per cent of consultations would save up to $300 million annually in travel and waiting times.[62] In a trial of using telehealth for older Australians living with chronic diseases, benefits included a 40 per cent reduction in the mortality rate and a 24 per cent saving over the year to the healthcare system.[360] Implementation of stable network infrastructure such as NBN and 5G – in conjunction with adequate data limits, affordable equipment and digital literacy – will play a key role in the successful functioning of telehealth and mHealth.

RECOMMENDATION 2

Improve equity of access to healthcare through technology.

Use of telehealth and AI-enabled devices must increase to support equitable outcomes for people living with disadvantage. These technologies can be used to improve access and reduce financial burden.

To improve equity of access to healthcare for all Australians, ATSE makes the following recommendations.

RECOMMENDATION 2.1

The Australian Government should incentivise the adoption of technologies designed to improve equity of access to healthcare across the country's vast distances and diverse communities.

Priority should be given to technologies that support integrated care models, such as:

a. Wearable monitors, apps, secure transmission of prescriptions and referrals, and AI-assisted reminders and scheduling
b. An integrated, standards-based telehealth platform applicable across multiple domains, including home telemonitoring, home tele-rehabilitation, residential care facilities, general practices, mental health support, community health centres and remote medical services

RECOMMENDATION 2.2

The healthcare sector should expand its adoption of mobile technologies for prevention, diagnosis, treatment, monitoring and support.

Mobile health can be used effectively as a low-cost intervention in prevention, and to deliver healthcare services to people when and where they need them.

a. Expansion of mobile health technologies will require agile, adaptive regulation. Additional resources will be needed for the Therapeutic Goods Administration to monitor and anticipate emerging technologies.

Access to, and use of, mobile technologies varies significantly within the Australian population and is influenced by a number of factors, including English literacy, technological literacy, health status, income, education, employment status and trust.[361] As well as structural factors, the adoption of new technologies is influenced by social influence, peer engagement, usefulness and ease of use.[362, 363]

Research on barriers to equitable access to new medical technologies was identified as an evidence gap during ATSE's consultations. Stakeholders also indicated that research into ways to improve regional and remote health outcomes would be of value.

In order to understand barriers to access and uptake of health technologies in Australia, ATSE proposes the following research priorities for investigation by social scientists with knowledge or expertise in social licence, patient behaviour or population health.

RESEARCH PRIORITIES

Research priority 2.1

How do remoteness, financial and cultural factors affect uptake of new health technology by patients and healthcare providers?

Research priority 2.2

What can be done to ensure health data is appropriately representative of minority groups in the population.

CSIRO STUDY ON TELEHEALTH FOR AGED CARE [364]

In 2016, CSIRO carried out Australia's first large-scale trial of telehealth for home monitoring of older patients with multiple chronic diseases. These patients account for more than 70 per cent of Australia's healthcare system expenditure. The telehealth device included clinician/participant video-conferencing capabilities and devices to monitor patient vital signs.

The benefits of telehealth achieved after 12 months included:

- 46.3 per cent reductions in the rate of MBS expenditure (savings of $611–$657)
- 25.5 per cent reduction in the rate of Pharmaceutical Benefits Scheme expenditure (savings of $44–$354)
- 53.2 per cent reduction in the rate of hospital admission (reduction of 0.22–1.0 hospital admissions)
- More than 40 per cent reduction in mortality
- More than 83 per cent user acceptance and use of telemonitoring technology
- More than 89 per cent of clinicians would recommend telemonitoring services to other patients

ISSUE 3

Workforce capability

Australia faces significant skills shortages in the healthcare workforce, particularly in digital literacy. Empowering the workforce to maximise the benefits from new healthcare, data and communications technologies will result in increased efficiency, better decision-making and improved health outcomes.

The training of healthcare professionals is critical. The National Digital Health Workforce and Education Roadmap, under development by the ADHA, will need full support. All levels of government should take action on the roadmap to assist the healthcare workforce in developing skills to adapt to a technology-driven workplace. Resources such as the Health Information Workforce census will be critical in identifying digital capability gaps and skills shortages.

Swift and accommodating curriculum approval processes will be needed to ensure that courses remain up to date with technological advancements in the healthcare sector. Qualifications and training must be agile and ongoing, supporting the healthcare workforce to adapt to changing technology, roles and tasks.

RECOMMENDATION 3

Support the existing and future healthcare workforce in the transition.

Existing and new members of the national healthcare workforce must be supported and empowered to retrain, adapt and develop skills in line with the requirements and benefits of new digital technologies.

RECOMMENDATION 3.1
All levels of government should provide ongoing support for the healthcare workforce to retrain, adapt and develop, in line with the National Digital Health Workforce and Education Roadmap under development by the ADHA. Qualifications and training must be agile and ongoing, supporting adaptation to changing technologies, roles and tasks.

RECOMMENDATION 3.2
Universities and vocational education and training (VET) institutions, in collaboration with industry and the professional peak bodies for healthcare providers, should create or modify courses and training options to include digital health literacy content in all health-related degrees.

RECOMMENDATION 3.3
Healthcare professional colleges and organisations that are responsible for continuous professional development should include new technologies and digital literacy in their curricula to upskill healthcare professionals via mechanisms such as micro-credentialing, short courses, industry secondments, mentoring and workplace exchange programs.

RECOMMENDATION 3.4
State and territory departments of education should strengthen the content and teaching of health literacy, digital literacy, and STEM.

Australia's health and medical workforce must evolve over the next decade in response to greater digitisation and personalisation of medicine, and the adoption of a more integrated, patient-centred approach. Evidence suggests that millions of jobs may be lost to automation over the next decade,[365] but there is limited research on the impact of automation on the healthcare and medical sector in Australia. Stakeholders identified the impact of digitisation and advanced technologies such as AI on the workforce as a key research priority for the near future. Stakeholders also noted that research on how to develop dynamic career pathways between research and industry would be of value.

In order to investigate the best mechanisms for supporting the existing and future healthcare workforce to adapt to increasing automation and digitisation, ATSE proposes the following research priorities for research organisations with knowledge or expertise in future scanning, with a focus on global forecasts for jobs and future workforce needs.

RESEARCH PRIORITIES

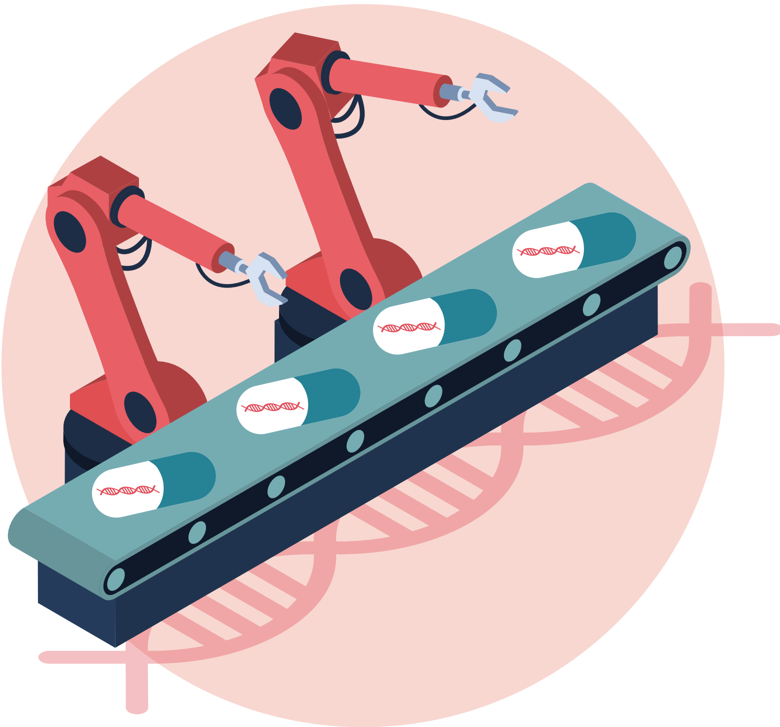
Research priority 3.1
How do future skill, job, infrastructure and technology needs map on to existing incentives and accreditation processes?

Research priority 3.2
How will automation and AI affect the healthcare workforce, both current and future?

ST STEPHEN'S HOSPITAL HERVEY BAY[366, 367]

Australia's first fully integrated digital hospital is St Stephen's Hospital Hervey Bay. Digital technologies in use at this hospital include the country's first full electronic medical record (EMR) and digital patient management systems. One of the key factors underpinning the hospital's success in catering for EMRs was its decision to include staff members in the journey. As a result, doctors and nurses have taken ownership of the software, thanks to their involvement in setting up the framework to adapt the software to an Australian setting. Staff members were also trained and taught how to work in a non-paper environment.

St Stephen's Hospital and the Royal Children's Hospital Melbourne are now recognised as two of the first HIMSS Analytics Stage 7 validated hospitals in Australia, which means that they have an advanced patient record system.



ISSUE 4

Commercialisation of MedTech research

Despite a thriving medical and life sciences research sector, Australia struggles with research translation and commercialisation. Government support for medical research is generous, but this support needs to be better targeted to and aligned with translation and pre-commercialisation activities. Australia's position as a world leader in health technology research is at odds with our poor translation and commercialisation record, indicating a system failure. Government has a responsibility to ensure that a clear pathway and support mechanisms enable the development of timely, cost-effective and commercially successful products from publicly funded Australian research.

The Australian Government must ensure that the relevant investment and regulatory frameworks are in place to create an environment in Australia where our health technology start-ups are attractive to investment. Such an environment can be achieved through strategic and targeted support for health technology researchers and start-ups in areas with high growth potential.

RECOMMENDATION 4

Provide targeted support for a thriving health technology sector.

Government must support investment in improving pathways to commercialisation for Australian-developed medical technology.

RECOMMENDATION 4.1

The Australian Government should take a strategic approach to funding areas of high potential growth with strong market need and commercial potential. Priority should be given to:

a. Proposals in which strong science addresses areas of validated and unmet need, where there is a clear commercial value proposition and competitive advantage for the product or service being developed.
b. Funding areas where government support can be leveraged to de-risk external investment.
c. Proposals with existing industry collaborations, or the potential for such collaborations.

RECOMMENDATION 4.2
Research institutions, including universities, should provide coaching on product development and commercialisation pathways to healthcare sector researchers, including intellectual property development and management, to ensure they can move from basic research funding to other investment attraction, and to more effective product development and translation where of interest.

a. This coaching should include assistance to develop a target product profile capturing the development and commercialisation path, along with a clear description of the unmet medical need (market size and structure) being addressed. It should also address the value proposition in the current and future competitive landscape, and the regulatory and market access strategy.
b. Research institutions should prioritise the attraction of suitably qualified people from industry to grow their translation and commercialisation expertise.
c. Research institutions should invest in upskilling technical transfer offices with stronger commercialisation skills, and should ensure that investment is in place for project capture and management.

RECOMMENDATION 4.3
Commercialisation success should be recognised and substantively taken into account when awarding peer-reviewed competitive grants, along with publication and patent records. This should involve the addition of commercially experienced members to all assessment panels.

RECOMMENDATION 4.4
Australian, state and territory governments should use their purchasing power to drive commercial opportunities, support innovation, and actively encourage value-based, preventative care, including through procurement and reimbursement systems.

A significant body of research has investigated the divide between academia and industry in Australia, which has been found to limit the domestic development and commercialisation of new medical products and technologies. However, there is limited research into international best practice in this area. ATSE's consultations and analysis revealed a research gap in terms of effective policy and regulatory and investment frameworks to support and promote research translation and commercialisation, including improving collaboration between academia and industry and accessing investment and global supply chains. Stakeholders reported that research into funding models and incentives to develop and commercialise technology would be useful.

RESEARCH PRIORITIES

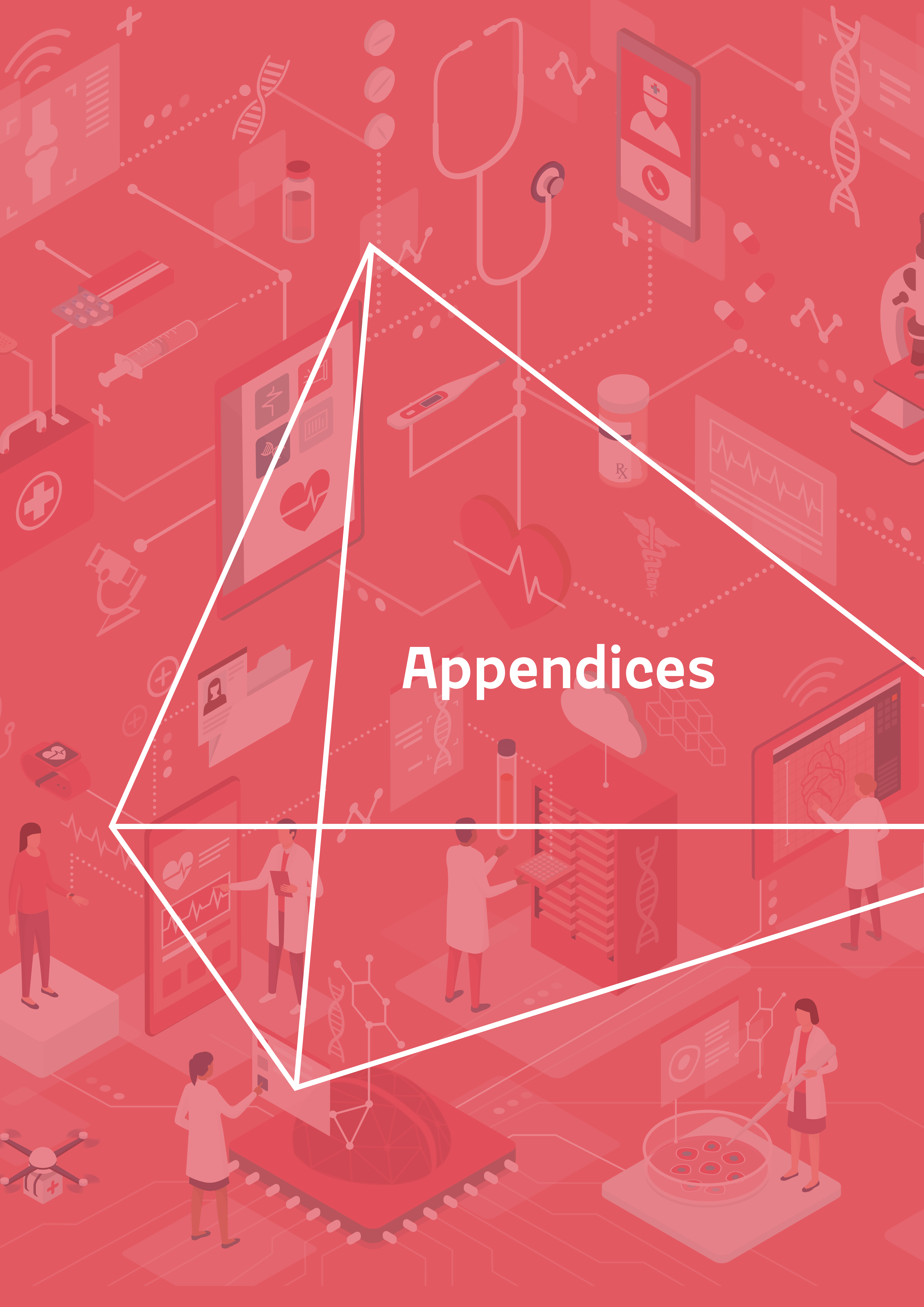
Research priority 4.1
How can international best practice in policy and regulatory and investment frameworks be applied in an Australian setting to support and encourage the translation and commercialisation of healthcare and medical research?

Research priority 4.2
What government support would provide access to investment, skills and global supply chains?

COCHLEAR LIMITED[368]

The bionic ear was developed from Professor Clark's pioneering research at the University of Melbourne during the 1970s. When research funds were running low, Professor Clark's research team obtained funding from the Australian Government and industry to bring the implant to the public. In 1995, Cochlear Limited was listed on the Australian Stock exchange as a separate company. Today, Cochlear Limited is the global leader in implantable electronic hearing medical devices, has a dedicated global team of more than 2,200 people and has changed the lives of more than 350,000 people.

Appendices

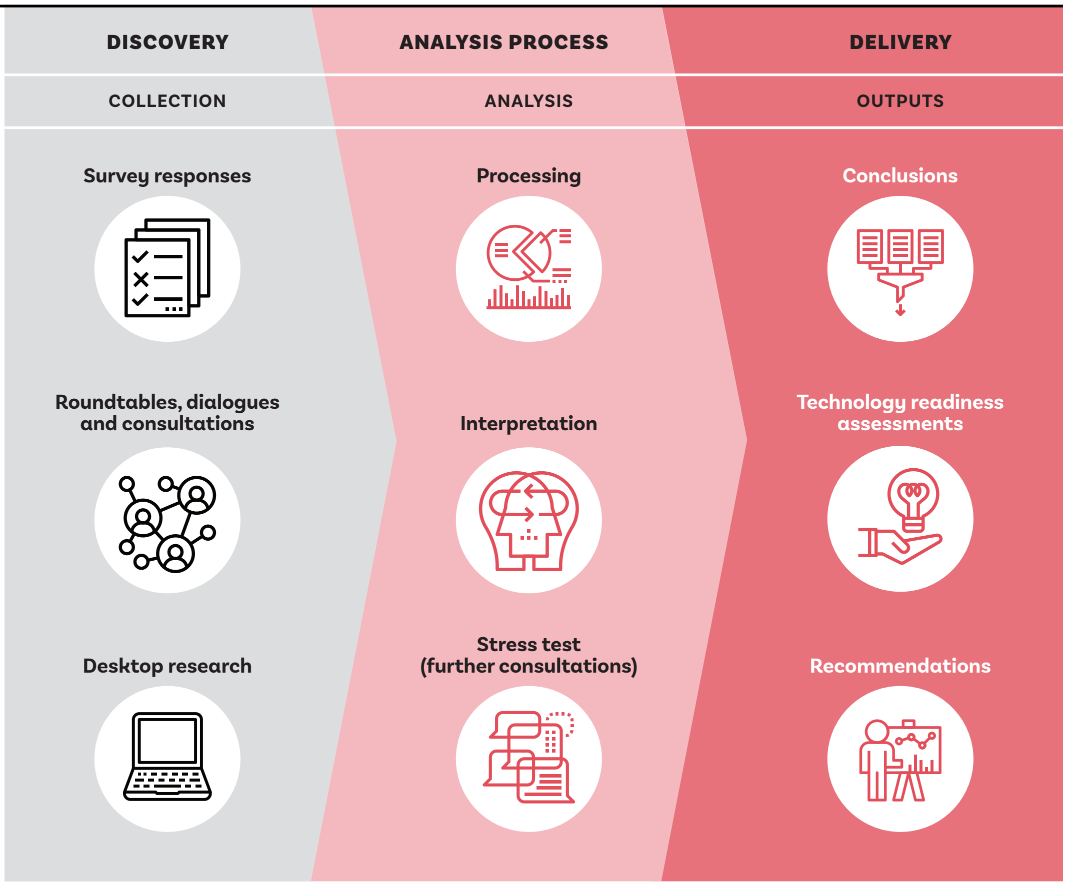


Appendix A

SUMMARY OF READINESS ANALYSIS

The final readiness assessments and recommendations were developed using a mixed-method convergent design, represented in Figure 13[369]. This means that both quantitative and qualitative data are used in the analysis process.

FIGURE 13
Project methodology used to generate ATSE's readiness indicators and recommendation



Findings from the quantitative and qualitative data streams were collected concurrently. The full breakdown of those consulted can be found in Table 15.

TABLE 15
Stakeholder consultations

CONSULTATION TYPE	DATE	LOCATION	NUMBER OF STAKEHOLDERS
Dialogue	17 June 2019	Melbourne, VIC	28
Roundtable	3 July 2019	Canberra, ACT	15
Roundtable	28 August 2019	Melbourne, VIC	30
Roundtable	4 September 2019	Videoconference	7
Roundtable	11 September 2019	Brisbane, QLD	17
Roundtable	24 September 2019	Sydney, NSW	22
Online survey	24 July – 19 November 2019	Online	101
Key stakeholders	December 2019 – January 2020	Offline	23
		TOTAL	**243**

Using the survey readiness as a baseline, ATSE identified areas that were convergent and/or divergent. Further research and consultations informed the preliminary readiness parameters and recommendations. The readiness assessments and recommendations were tested with four key groups: the project's Expert Working Group, ATSE's Health Technology Forum, the project Steering Committee and key stakeholders from government, industry and research organisations.

For each potential exemplar solution, the consultation analysis and internal reasoning that contributed to the readiness assessment are included in the following appendix tables:

- **DATA AND DIGITAL SOLUTIONS** — Table 16
- **PRECISION MEDICINE SOLUTIONS** — Table 17
- **INTEGRATED CARE TECHNOLOGIES SOLUTIONS** — Table 18

The tables are a summary of industry stakeholder insights from consultations and desktop research. For a detailed discussion, see Chapter 4

TABLE 16

DIGITAL AND DATA SOLUTIONS

INFRASTRUCTURE & SYSTEMS READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Infrastructure & systems readiness	FINAL WEIGHTED AVERAGE 45% RESPONSE BY SECTOR • Industry 44% • Gov: 50% • Research: 43% • Other: 42%	• Digital health services, including telehealth, digital health, apps, gamification/wearables and online triaging, improve access to primary and specialist care, and remove regional and financial barriers. • Lots of good data from wearables and emerging systems. Will have an idea of health prospects. • Implementation of My Health Record is a huge step. • The National Digital Health Strategy and Action framework. • Australia has strong structures in place, such as medical services advisory committee and evaluation groups which are government-funded to undertake technology assessment.	• Improved NBN infrastructure is necessary for telehealth and enhanced access and equity. • Hospitals need better virtual infrastructure for the adoption of digital health technologies. • Regional access to health services is limited. • Need to improve continuity of care from different providers, as it is currently a fragmented system. • Need to be able to trace people's journey through the system. • Need decision-making support technology to assist clinicians. • The overwhelming majority of information on patients is not shareable. • The need for information that matters to the consumer and the clinician. • Large volumes of data are not the solution unless there is actionable insight. • NBN should be an economic driver. Need infrastructure to support collaboration. Funding infrastructure should look at the commercialisation potential of new technology. • Benefits of using new technology must be demonstrable.	• As of 28 July 2019, 16,400 healthcare provider organisations were registered for My Health Record.[271] • The National Digital Health Strategy found that the economic benefit of secure messaging could be approximately $2 billion over 4 years, and as much as $9 billion over 10 years.[53] • The 2019-20 Budget allocation for the Medical Research Future Fund provided $80 million for data infrastructure.[281].	• One third of Australia's population live in rural or remote locations.[156] • Australia is facing rising domestic cyber threats. • 90 per cent of organisations experienced some form of cyber-attack during 2015-16.[370] • The 2018 Health Information Society of Australia (HISA) survey of Australian health organisations found that 68 per cent of organisations have a documented cybersecurity procedure (up from only 44 per cent in 2017), and 60 per cent of respondents knew what procedure to follow in the face of a cybersecurity incident.[191] On average 73 per cent of Australian healthcare providers have a formal governance plan which addresses the management of cybersecurity issues, and only 36 per cent perform an annual cybersecurity risk assessment.[283]	DECISION Leave Harvey Ball at 50% REASONS • Limited platforms for data sharing. • Lack of connectivity and compatibility between healthcare platforms and software. • Poor data standardisation. • Preference towards older technologies and use of paper-based systems. • Cultural shift required to move technology along. • Equity of access to digital and data healthcare. • Main challenge will be the integration of digital technologies into clinical settings. • Integration and effective utilisation of these technologies will require a fast and stable network connection, appropriate data storage infrastructure, and a significant financial investment by health organisations to overhaul old technologies and systems.	◐

DIGITAL AND DATA SOLUTIONS

Skills availability

2

SKILLS AVAILABILITY

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Infrastructure readiness	FINAL WEIGHTED AVERAGE 41% RESPONSE BY SECTOR • Industry: 46% • Gov: 45% • Research: 43% • Other: 30%	• Highly qualified workforce and strong medical research sector. • Excellent breadth and depth of talent in universities. • Australia is an excellent testbed for the health market. • Clinicians are decision-makers and need more support to make decisions. • Australia has a strong base of artificial intelligence research compared to US and China. • For many years there has been an ongoing effort to strengthen health and STEM education. • An objective of MTPConnect is to support initiatives that improve the management and workforce skills; including prospective healthcare models and integration of advanced technologies.	• Lack of education in health technology within medicine degrees. • Lacking in skills for digital health. • Need to incorporate data science skills into health degrees. • Need health economists. • Need to get students into industry, and retain early career researchers. • Lack of workforce readiness. • Workforce needs more multidisciplinary training. Need to integrate clinical skills with skills in data, engineering and software. • Both current and future clinicians need training to develop their technology-related skills to improve adoption. This could be achieved through micro-credentials, workplace training, life-long learning, swift curriculum changes etc. • The use of technology to support clinicians will reduce stress and workload. • Jobs need policy focus. • Need to translate and integrate research into the clinic. • Need more multidisciplinary and collaborative work. • Need an education program that feeds the information back to the patients.	• Development of a workforce (healthcare professionals and Chief clinical information champions) with strong skills in applying digital health technology is one of the strategic priorities of the National Digital Health Strategy (2018).[53] • Healthcare and social services employ 22.2 per cent of Australian PhD graduates.[287] • There is a routine census conducted every three years of the Australian health information workforce.	• Australian industry will need up to 161,000 AI workers by 2030 with expertise in machine learning, computer vision, natural language processing and other AI technologies.[294] • More than 50 per cent of Australian workers will need to be able to use, configure or build digital systems in the next 2-3 years, and more than 90 per cent of Australians will need to use some level of digital skills at work within the next five years.[284] • Australian Institute of Health and Welfare (AIHW) reported on the coding workforce shortfall in 2010.[371]	DECISION Reduce Harvey ball to 25% REASONS • Need to integrate digital skills into medical education. • We have a highly qualified workforce but need multidisciplinary training. • Will require a digitally literate workforce, so education and training of the existing workforce is critical. • Medical students need more industry exposure and multidisciplinary courses. • Need to also focus workforce and education for the health information workforces.	

Social & ethical readiness

3

SOCIAL & ETHICAL READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Social & ethical readiness	FINAL WEIGHTED AVERAGE 37% RESPONSE BY SECTOR • Industry: 38% • Gov: 35% • Research: 40% • Other: 32%	• General acceptance towards a data-driven society. • Australians are ready adopters of new technologies. • Patients have a willingness to share data especially when it's de-identified. • My Health Record data can be used for research and public health purposes subject to meeting statutory requirements.	• Equity of access – Regional and cultural access to technology should be considered, underrepresentation of groups in health data is a concern. Telehealth, transport and NBN access will improve equity. • Lack of understanding around who owns the data. Particular concerns around DHR and MHR and risk of patient disengagement. • To have a social licence, need to build consumer trust and engagement, especially around data privacy. Bring them along the journey. • Cultural shift required to move technology along and become more adaptable. • Still low levels of health literacy in Australia, not everyone wants to take care of their own health.	• 9 out of 10 Australians have a My Health Record. • 58 per cent of Australians feel that sharing information is a key benefit of digital health technologies.[54] • 70 per cent of Australians think healthcare providers could use digital technology and the internet to improve patient experience.[54] • 90 per cent of GPs, pharmacies and public hospitals are registered with the MHR service, and in December 2019 there were around 220,000 views of the MHR by GPs and 130,000 views by public hospitals. For more information: https://www.myhealthrecord.gov.au/statistics	• The number of health services per capita for very residents of remote regions is less than half of that of those of major cities.[292] • 91 per cent of Australians rate privacy as a significant concern.[54] • Acceptance of digital technologies amongst health practitioners is impacted by their perceived impediment to their ability to make independent diagnoses, and to their relationship with patients.[289] • Majority of Australians now have a My Health Record, while less than five per cent have accessed it more than once in December 2019 nearly 13 million consumers had data in their records that could be used by their healthcare providers on their behalf when providing care. • 11 per cent of residential aged care facilities are registered (4 per cent of all types of aged care facilities), six per cent of allied health services, 33 per cent of private hospitals. • Pathology and diagnostic imaging services, 43 per cent are registered.	DECISION Decrease Harvey Ball to 25% REASONS • People are undecided about accepting new technologies. • People are open to digitisation, but there's a concern particularly around privacy and digital health records. • People don't know who owns their data and are afraid of how data will be used (e.g. health insurance premiums). • Need to continue building trust. • Consumers need access to data on institutional and practitioner outcomes to inform choice. • Include patients in early stages of design. • Health data must be representative of all populations in Australia in order to gain a full picture of the nation's health. • Provide equitable health solutions for those with poorer health outcomes.	

Economic & commercial feasibility 4

ECONOMIC & COMMERCIAL FEASIBILITY

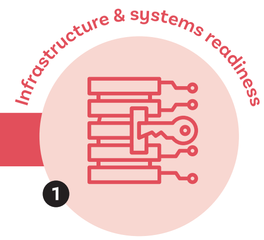
READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Economic & commercial feasibility	FINAL WEIGHTED AVERAGE 44% RESPONSE BY SECTOR • Industry: 48% • Gov: 40% • Research: 48% • Other: 41%	• Strong medical research sector. • Commercial feasibility increases when developing a regulated product. • Interoperable data platforms will drive innovation and research. • My Health Record data, when approved, can be used for research and public health purposes.	• Poor commercialisation track record. • Downward trend on investment in R&D. • Funding models need further development to incentivise commercialisation. • We can't commercialise in this space without health economists. • To support start-ups and small businesses, need to reduce risk, provide more funding opportunities, and highlight case studies of successful SME's, reduce regulatory barriers, provide mentorship support and create a push for more investment in science and technology companies. • Need to retire high-cost low yield tech, focus on prevention and wellness. AI, machine learning, medical devices, sensors, surgical robots and POC technology will be key tools. • A patient-centred approach to design and more communication and collaboration between industry, academia and health services will be necessary. • Medical funds towards medical devices but not medical software. • The right data policy framework in place will shape the commercial landscape in which companies operate.	• McKinsey and Company estimate that, based on current technology alone, digitalisation could add up to $250 billion to Australia's GDP by 2025.[298] • Through automation, increased connectivity, and utilisation of advanced data analytics, Australia's annual healthcare expenditure could be reduced by up to 12 per cent.[298] • The introduction of secure messaging technologies could offer a gross economic benefit of $9 billion over 10 years.[53] • The 2018-19 Budget included a $9.6 billion investment in research and development.[372]. • Medical Research Future Fund (MRFF) set to reach $21 billion by 2021.[373] • A PwC study of integrated EMR benefits at the Princess Alexandra, Mackay Base, Cairns, Townsville and Queensland Children's Hospitals showed $181.9 million financial and economic benefits have been achieved across patient quality and safety, operational service improvement and direct financial savings.[374] • Royal Children's Hospital in Victoria EMR after 12 months being implemented has delivered benefits to patients, including a 27 per cent reduction in medication prescribing and administration errors.[375]	• Australia's gross expenditure on R&D (GERD) as a product of GDP has decreased from 1.88 per cent in 2015-16 to 1.79 per cent in 2017-18[376], significantly lower than the OECD average of 2.3 per cent.[377] • Only 16 per cent of government funding for innovation programmes specifically encouraged knowledge translation in 2016-2017.[331]	DECISION Leave Harvey Ball at 50% REASONS • The high cost of developing and integrating technology. • Funding models need development. • Supporting STEM start-ups and SMEs to translate applied research will improve innovation capacity. • Some support exists for the domestic development of digital health technology. • Collaboration between researchers, industry and the primary health system (hospitals, clinics and other primary care providers) is critical for the development of digital health technologies.	◑

POLICY & REGULATORY READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Policy & regulatory readiness	FINAL WEIGHTED AVERAGE 32% RESPONSE BY SECTOR • Industry: 33% • Gov: 25% • Research: 34% • Other: 33%	• TGA ensures safe technology, has recently restructured and can adjust to new technology. • TGA, CSIRO and MTPConnect are working together to develop an adaptive regulation system. • Build public confidence and awareness. • ADHA working hard on managing privacy. • National Data Commissioner role to assist in data privacy. • Work has started in primary care to standardise data within the electronic health record.	• Need standardisation of data and EMRs. • Patient data ownership needs addressing. • MHR stewardship needed regarding integration into the health system and addressing data privacy concerns. • Fast-moving technologies outpace regulation and standardisation, regulations are unadaptable. • Privacy and data protection is lacking. • Need to embrace failure & risk-taking. • More agile regulatory and policy space for SME's. • Need to support the donation of de-identified data (opt-out models). • Software is not considered a medical device, it is unregulated and unfunded. • Adoption of new standards such as Fast Healthcare Interoperability Resources (FHIR), Systematised Nomenclature of Medicine Clinical Terms (SNOMED-CT), Australian Medicines Terminology (AMT) across all of healthcare using a common national approach is foundational and critical for primary, secondary and tertiary care sectors. • Governance arrangements need to cover whole spectrum of data use such as patient access, clinicians sharing data, use of data for secondary purposes, storage and linkage of data from multiple sources. • Gain public confidence by providing clarity around the rights of people to control, correct and determine access to their own health data, and those of dependents. Additionally clarity on cross border disclosure of personal information, storage, data transfer and use.	• As of July 2019, 90.1 per cent of eligible Australians were participating in My Health Record.[89] • Current efforts towards digital health include Australia's Digital Health Strategy which proposed seven strategic priorities to be achieved by 2022, including a rollout of My Health Record for health data management and communication, and a National health interoperability strategy and roadmap.[53] • The Privacy Act and My Health Record Act specify obligations of parties that hold health data and the rights of people over use and access of their data.	• Data privacy is a major policy challenge, with 69 per cent of Australians are more concerned about data privacy than they were 5 years go.[304] • Currently on average only 65 per cent of Australian healthcare providers have a formal governance plan which addresses the management of cybersecurity issues, but only 33 per cent perform an annual cybersecurity risk assessment.[191]	DECISION Leave Harvey Ball at 25% REASONS • Fast-moving technologies outpace regulation and standardisation. • Regulations are not agile. • Standardisation of data is required. • Need an ethical framework when using health data for research or clinical outcomes. • Need strong, enforceable regulation of health data privacy, security and usage by organisations that hold that health data, including in the sharing mechanisms between third parties.	

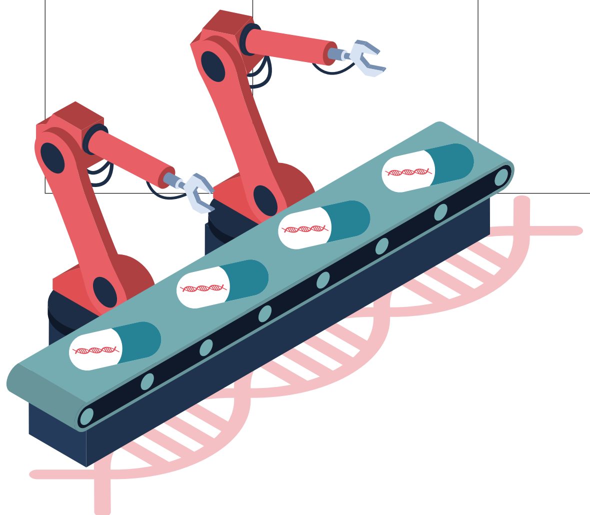
TABLE 17

PRECISION MEDICINE



INFRASTRUCTURE & SYSTEMS READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Infrastructure & systems readiness	FINAL WEIGHTED AVERAGE 45% RESPONSE BY SECTOR • Industry: 45% • Gov: 35% • Research: 51% • Other: 48%	• Artificial intelligence will allow better personalisation of treatment. • Largely doing exome sequencing to get a diagnosis. • Biomarkers can be used for early-stage prevention and tailoring treatment.	• Can be used with machine learning, however, bias could be present in data sets and outcomes which could impact predictive diagnostics. Need better interoperability of data platforms and software, need to stop using paper-based systems. • Need to deploy this across the country in a variety of settings, individual and broadly on populations and communities.	• Australian Genomics Health Alliance (AGHA) aims to integrate genomic medicine into Australian healthcare. • Every year over 1000 new clinical trials are commenced, representing an estimated $1.1 billion of direct expenditure.[314] • R&D tax incentives reduce clinical trial costs compared to our international counterparts. Early phase clinical trials in Australia are 60 per cent cheaper than the US after-tax incentives.[314]	• The capture, storage, management and use of clinical omics data must be standardised and integrated with the digital health agenda through My Health Record.[378] • Data sharing, security, computing and storage requires connected systems, especially in rural, remote, Aboriginal and Torres Strait Islander communities and for population-wide level testing.[378] • Computing and data storage infrastructure to support the storage, sharing and curation of sequence data is a major challenge.[37]	DECISION Leave Harvey Ball at 50% REASONS • Australia well placed in these technologies but the co-ordination in data-infrastructure and omics technologies is a limiting factor. • Equity of access to these technologies should be considered. • Lack of multidisciplinary and interdisciplinary networks to facilitate greater clinical trial capacity. • Lack of computational and data storage infrastructure to support the storage, sharing and curation of sequencing data.	◐



PRECISION MEDICINE

SKILLS AVAILABILITY

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Skills availability	FINAL WEIGHTED AVERAGE 42% RESPONSE BY SECTOR • Industry: 43% • Gov: 35% • Research: 45% • Other: 45%	• Strong research sector. • Innovative clinicians.	• Bad on implementation of research. • Need an increase in the workforce for genetic councillors, sequencers and interpreters.	• Australia has 37 clinical trial networks currently in operation, with an estimated workforce of 6900 highly skilled staff involved in conducting over 1000 clinical trials annually.[314] • Inclusive of medical research, the medical technology, biotechnology and pharmaceutical sector supports more than 110,000 jobs.[380]	• Australia has an estimated workforce of 150 clinical geneticists, 97.8 per cent of whom are working clinically[9], and 480 genetic counsellors, 45 per cent of whom are working in clinical roles.[313] • Little investment has been made in the development or delivery of education programs, activities and resources, with only 59 education activities or resources nationally.[242] • Australia will need to review workforce gaps to be prepared for the increase of precision medicine technologies approaching early-phase testing.[381]	DECISION Leave Harvey Ball at 50% REASONS • Strong research but lacking commercialisation skills. • A shortage of clinical genomics specialists and improve genomic literacy in the current medical workforce as these technologies become increasingly integrated into medical practice at the point of care. • Clinical trial expertise will also become increasingly important over the coming decade with advances in precision medicine development.	◑

SOCIAL & ETHICAL READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Social & ethical readiness	FINAL WEIGHTED AVERAGE 39% RESPONSE BY SECTOR • Industry: 41% • Gov: 40% • Research: 44% • Other: 32%	• Technology is generally accepted by society and consumers are willing to adopt the technology. • Personalisation also refers to the empowerment of the patient, and the capacity for the consumer to ask the doctor to make the decision for them.	• Access and equity issues remain, with the technology only being available to those who can afford it. • Insurance implication, and what it means for a person's insurance premiums. • Ethically, how should you roll out these technologies?	• 75 per cent of consumers (in a public opinion polling) would be willing to use genetic testing to identify the most effective drug to treat their disease. Of those people, 95 per cent willing for their results to be used to improve treatments for future patients.[382] • Genetic screening could reduce gene variant-attributable cancers by up to 28 per cent, cancer deaths by up to 31 per cent.[311] • Currently, 700,000 genetic tests are performed annually in Australia, which is a 70 per cent increase in molecular testing within the past 5 years.[316] • The Financial Service Council, the peak body for insurance companies which sets standards and codes of conduct, has introduced a moratorium on the use of genetic information in life insurance policy applications which will be effective from 1 July 2019 to 30 June 2024.[319]	• Precision medicine technologies raise specific ethical concerns relating to the development and testing of novel gene editing and cell therapies, genomic data privacy and consent, and equity. • Currently, only 43 per cent of Australians report being willing to donate their de-identified genetic data to universities or research agencies for research purposes, and 39 per cent would allow a digital app to analyse their data to profile their risk of disease.[315] • About fifty per cent of consumers were familiar with the concept of precision medicine.[382] • Need to include rural, remote, Aboriginal and Torres Strait Islander communities in databases to make it equitable.[383]	DECISION Leave Harvey Ball at 50% REASONS • Social acceptance for the technologies, but ethical, access and equity issues remain. • Need broad education of the workforce and the public on precision medicine, including the use and storage of genomic data. • There is a gap between rural and urban access to precision technologies. • Addressing issues of equitable access is the first step to ensuring Australia realises the benefits of this technology.	◐

ECONOMIC & COMMERCIAL FEASIBILITY

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Economic & commercial feasibility	FINAL WEIGHTED AVERAGE 40% RESPONSE BY SECTOR • Industry: 46% • Gov: 30% • Research: 47% • Other: 37%	• High-quality clinical trials and early phase studies. • Excellent medical device innovation. • High-quality research and development. • Bespoke technology useful. • As technology improves, the cost of sequencing will come decrease. • The MRFF represents a genuine opportunity to alter healthcare outcomes.	• A poor track record for collaboration between academia and industry, government should drive commercialisation. Need more funding for businesses to undertake R&D. • Bespoke technology expensive, need to fund clinicians to give the best treatment. • As you become more precise, the costs increase and it becomes more difficult to be achieved by the market. • MRFF funding decisions that are made often appear to be capricious, poorly refereed, and lacking in a strategic direction.	• A poor track record for collaboration between academia and industry, government should drive commercialisation. Need more funding for businesses to undertake R&D. • Bespoke technology expensive, need to fund clinicians to give the best treatment. • As you become more precise, the costs increase and it becomes more difficult to be achieved by the market. • MRFF funding decisions that are made often appear to be capricious, poorly refereed, and lacking in a strategic direction.	• There has been no formal mechanism for governments to strategically coordinate investment to support the implementation of genomic testing in health systems.[385] • Precision medicines present a new challenge regarding evaluation, Medicare subsidisation, and coverage by private health insurance, raising questions about which genetic testing services should be publicly funded. • SMEs and start-ups face challenges in scaling up, with strong international competition and limited incentives for domestic manufacturing of medical devices and products. • The cost of precision medicine can be prohibitive. One recently approved precision medicine drug, Spark Therapeutics Luxturna™ for retinal dystrophy, the first drug for treatment of inherited disease and has a list price of US$425,000 per dose, making it the most expensive drug in the USA.[253]	DECISION Decrease Harvey Ball to 25% REASONS • Genome modification, such as CAR-T cells, are expensive to manufacture. • Improving investment in start-ups. • Equitable access to rural and metropolitan areas. • Cost-benefit assessment is difficult to justify. Value to the system is unrecognised. • Notable commercialisation gap in Australia's medical sector, known as the valley of death. • Need the right regulatory environment to attract domestic and international investment.	

POLICY & REGULATORY READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Policy & regulatory readiness	FINAL WEIGHTED AVERAGE 38% RESPONSE BY SECTOR • Industry: 41% • Gov: 40% • Research: 40% • Other: 33%	• A good regulatory system for dealing with the technology. • Some frameworks are ready.	• To prevent misuse, need guidelines on using and prescribing precision medicine correctly. • Diversity of new technology and the speed of proliferation presents a challenge for the assessment, accreditation and funding models for public health. • Regulation frameworks for clinical trials, laws, insurance and funding doesn't fit the model for precision medicine, this will challenge this space. • Refer to the individual. • Need standards around how to protect genomics data.	• In 2017, all COAG Health Council members committed to the first National Health Genomics Policy Framework.[22] • In April 2019, the Government amended the Gene Technology Act 2001, reducing regulatory barriers to gene-editing research.[386] • NHMRC National Statement for Ethical Conduct in Human Research governs research projects using genomic data.[387] • The Financial Service Council (FSC) introduced a moratorium on the use of genetic testing information in life insurance policy applications, until June 2024.[319]. • TGA approving Australia's first CAR-T therapy in December 2018, Novartis' CAR-T product Kymriah®. • The Centre for Law and Genetics (CLG) at the University of Tasmania has a focus on ethical, legal and social implications of gene technologies, and engages in domestic and international collaborative research on innovative health and genomics technologies. • Opportunities are increasing for gene editing approaches, with the recent decision by the Australian Government not to regulate gene-editing techniques in plants, animals and human cell lines which do not introduce new genetic material.	• Regulators require robust evidence supporting the replacement of existing medicines with precision medicines, and clinical validation of new technologies is a challenge.[226] • Determining statistical significance in efficacy of precision medicines across a population is a major challenge.[318]	DECISION Increase Harvey Ball to 75% REASONS • The Therapeutic Goods Administration Regulation regulates new precision medicine products such as genomic sequencing technologies, gene editing therapies and cell therapies. • TGA is fairly ready, and has recently released a strategy for improving responsiveness to new health products and technologies. • Policy frameworks around procurement and funding for precision medicines are strong. • Clinical trial environment in Australia is strong and well supported. • Australia has a number of collaborative research initiatives examining regulatory mechanisms for emerging medical technologies in the precision medicine space. What barrier exists to 100 per cent readiness? • Regulatory environment is evolving, and will take time to develop the best system for responding to new complex precision medicines.	

TABLE 18

INTEGRATED CARE

INFRASTRUCTURE & SYSTEMS READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Infrastructure & systems readiness	FINAL WEIGHTED AVERAGE 43% RESPONSE BY SECTOR • Industry: 44% • Gov: 50% • Research: 39% • Other: 38%	• AI and ML are increasingly becoming important diagnostic tools and will improve access to specialist care. • Queensland is in a unique position with state-wide EMR system. • Looking at the national digital health systems around the world, there is nothing like Australia which is completely consumer-controlled. We are a global focus at the moment. • MHR is an incredibly useful tool. • Medical device infrastructure in Australia is good.	• Must address inter-operability, data quality/representation and privacy issues to facilitate uptake. Health records are fragmented between public and private systems. • The overwhelming majority of major sectors and hospitals and public health facilities have no capacity to share data. • The health ecosystem contains siloed providers. • Standardised benchmarking and reporting. • The National Digital Health Strategy must progress. • Need to have an electronic prescription system that works well. • Health is state-based with some Commonwealth overview and Implementing systems is difficult when working across multiple state-based systems. • Lack of understanding around the definitions of technology leads to lack of trust. • Need investment and implementation of the infrastructure to adapt My Health Record into current models of care.	• Up to 50 per cent of health organisations indicated they were currently investing in new technology solutions, and that technologies which are already making the biggest impact were healthcare portals (25 per cent), EMR (22 per cent) and telehealth (20 per cent).[175]	• 61 per cent of healthcare providers said currently there are ineffective central systems and processes for patient lifecycle management, and a further 58 per cent reported inefficient hospital-to-patient communication.[343] • The main barrier to digitisation in hospitals is finance, with 53 per cent of health organisations reporting budget limitations as the biggest inhibitor of their ability to support technology-driven patient-centred care.[175] • An estimated 14 per cent of pathology tests are ordered due to a lack of access to patient history.[53]	DECISION Decrease Harvey Ball to 25% REASONS • Issues with secure, robust affordable and accessible internet connectivity. • State-based systems that aren't connected. • Patient data is not shared across different states and territories. • Errors in software. • Cybersecurity. • Connectivity and communication lacking. • State and federal based models. • Equity of access to rural and remote areas. • Lack of standardisation. • The integration of interfacing tools and services will require significant economic investment, and a coordinated approach.	◔

SKILLS AVAILABILITY

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Skills availability	FINAL WEIGHTED AVERAGE 46% RESPONSE BY SECTOR • Industry: 51% • Gov: 60% • Research: 41% • Other: 31%	• Healthcare providers in Australia are of excellent quality. • Australia has strengths in education in engineering, science and medicine and a fresh innovative SME sector. Great success in the medical device and medical technology sector. • Clinicians are technology friendly, like to explore new technology and are good at providing detailed feedback.	• There's not a collaborative culture between clinicians. • Skills and training of current and future workforce – Healthcare workers need the relevant training so that they can optimise the available technology. Career insecurity around moving into industry, as it becomes hard to get back to research. Need to embed digital health literacy in health professional's education. Micro-credentialing is a good way of reskilling the current workforce. • Need to address technology skills in current and future clinicians to improve adoption. Different models: micro-credentials, workplace training, life-long learning etc. Jobs need policy focus.	• Currently, 83 per cent of health organisations reported that upskilling, workforce planning and retention are a key priority for their organisation.[175] • 46 per cent of healthcare providers already use digital tools to share electronic health records with other practitioners, and a further 49 per cent would like to.[271]	• The implementation of integrated care technologies will require changes within the workforce and working environments, including the advent of new leadership and management roles such as nurse-led care or case management, and new professional roles involving pharmacists, nursing staff and allied health professionals.[346] • A 2019 HAYS recruitment survey found that 61 per cent of businesses report difficulty in recruiting cybersecurity talent.[388]	DECISION Decrease Harvey Ball to 25% REASONS • Seamless healthcare between different healthcare providers is lacking – handwritten paper-based records still exist. • Integrating primary healthcare with secondary healthcare. • Concerns that technology will replace the human care model – these technologies are here to assist the clinicians. • Interpretation of data and IT structure. • Relies heavily on digital and data skills. • The skills gap in terms of digital health literacy, collaboration, data management, data analysis, communications, and care coordination. • Need competency in data literacy. • Lack of cybersecurity training and awareness within health organisations.	

Social & ethical readiness

3

SOCIAL & ETHICAL READINESS

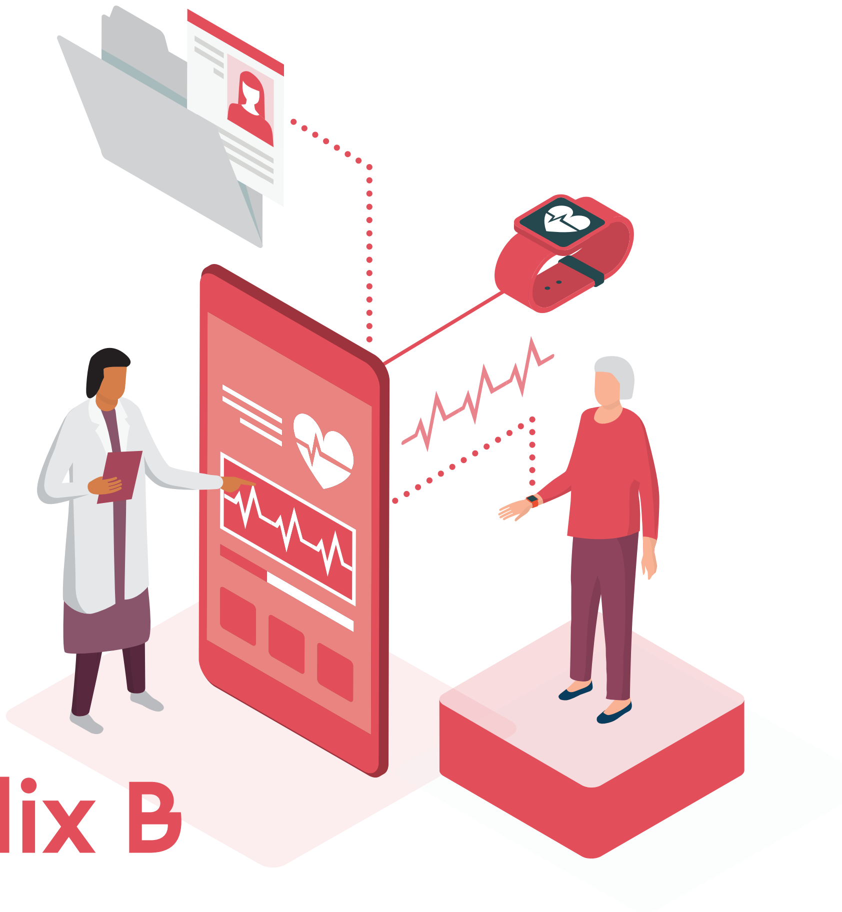
READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Social & ethical readiness	FINAL WEIGHTED AVERAGE 51% RESPONSE BY SECTOR • Industry: 57% • Gov: 65% • Research: 48% • Other: 35%	• Technology is generally accepted by society and consumers are willing to adopt the technology. • Australia is a healthy nation. • 3rd in the world for clinical trials in terms of population density.	• Cultural change needed for the uptake of new technologies. • Need to focus on prevention. • Need to include training and education of staff to reduce stress levels and non-compliance.	• Technology improves patient satisfaction and compliance in the UK, with 97 per cent of patients reporting high satisfaction and 94 per cent having better treatment compliance after using technology to manage or coordinate their care.[290] • The Productivity Commission's review on integrated care found that 84 per cent of Australian doctors believe patients should have access to their EMR's, and 49 per cent believe patients should be able to edit or update their own information.[70]	• Australians are experiencing increasingly complex care, with 15 per cent of people seeing more than 3 or more health professionals for the same condition, of these 71.6 per cent stated that at least one health professional assisted in coordinating their care[335]. • 18 per cent of regional or remote residents reported issues caused by a lack of communication between health professionals, compared to 13 per cent of people living in major cities.[335]	DECISION Increase Harvey Ball to 75% REASONS • We're ready, but there are still access and equity issues, and acceptance of the transition by clinicians. • Need more of a team culture rather than siloed intervention. People work in their disciplines of siloes. There's not a collaborative culture between clinicians. • Lack of willingness to adopt technology — a cultural issue. • Require equitable access to patient platforms and interfacing technologies.	

ECONOMIC & COMMERCIAL FEASIBILITY

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Economic & commercial feasibility	FINAL WEIGHTED AVERAGE 44% RESPONSE BY SECTOR • Industry: 47% • Gov: 45% • Research: 46% • Other: 37%	• Good health ecosystem, industry wants to work with us. • Australia is good at commercialising medical devices, and at developing research and translational tools. • Health and Medical research commercialisation receives significant Government support[389].	• Health as a cost rather than an investment, and the health system has no incentives to keep people healthy. • Cost of uptake. • Funding models, including Commonwealth, state and private. • Technology creation should be better supported, cost is a major barrier, different 'buckets' of money prevents overhaul of systems. Need patient engagement in design. Siloing of colleges, departments and services limits innovation. • NBN should be an economic driver. Need infrastructure to support collaboration. Funding infrastructure should look at the commercialisation potential of new technology. • Disinvestments in low-valued technologies is required. • A decision to fund: need a system that recognises the different levels of value technology can bring in, how it works and is delivered. • A financial burden of transitioning to new systems. • Need research into more effective and cost effective ways of making use of existing what information and technologies.	• The use of telehealth for 10 per cent of consultations would save up to $300 million annually in travel and waiting times.[70] • In recognition of the significant health and life expectancy gaps, funding to support greater access to primary care for Aboriginal and Torres Strait Islander patients has recently been announced, with $7.2 million allocated for Indigenous Primary Care to deliver coordinated care packages.	• Most GPs are funded by the Medicare Benefits Schedule (MBS) funding model, which does not offer financial incentives for health practitioners to avoid high-cost activity, use low-cost activity such as phone consultations, limit future consultations, promote preventative health strategies, or engage in team-based care.[70] • Australia's health system operates under a series of budget silos, which is financially inefficient and inhibits progress towards integrated care. • In 2015, the burden of disease in remote and very remote areas was 1.4 times as high as major cities.[292]	DECISION Decrease Harvey Ball to 25% REASONS • Funding models, including Commonwealth, state and private. • Decisions haven't evolved on how to fund. • Funding system setup for episodic care (individual) instead of treating the patient for all the issues. • Health organisations will need to undergo significant digitisation. • Economic readiness will be a greater challenge to regional and remote healthcare providers.	◔

POLICY & REGULATORY READINESS

READINESS PARAMETER	SURVEY: READINESS INDICATOR	SUMMARY: STAKEHOLDER INSIGHTS		SUMMARY: DESKTOP RESEARCH		ATSE INTERPRETATION	READINESS INDICATOR
		STRENGTHS	CHALLENGES	STRENGTHS	CHALLENGES		
Policy & regulatory readiness	FINAL WEIGHTED AVERAGE 40% RESPONSE BY SECTOR • Industry: 45% • Gov: 50% • Research: 40% • Other: 25%	• TGA and FDA have clear rules about what will be approved.	• Regulatory barriers are prohibitive for the uptake of new technologies. • Need regulation across services to check implementation standards, and to encourage digital health, teleservices. • Need the capacity to move faster on regulations, and that's whether its safety, efficacy or reimbursement • Policy change in the way people are reimbursed for care will be the step change catalyst. • The perception that law is a response, need broad legislations that recognise new technologies which demand a fit for purpose. • Need to standardise the privacy acts between all clinicians. • Filling private hospital beds before public.	• In 2016, all states and territories signed bilateral agreements (COAG 2016) to develop reforms to improved coordinated care in order to improve patient outcomes and reduce burden on public hospital services. • The National Digital Health Agency's Framework for Action (2018) reports that state and territory governments will have responsibility for developing and implementing ICT, and to collaborate with other jurisdictions to leverage cross-jurisdictional core ICT systems for seamless sharing of health information. • Due to our geographic size and diversity of population, Australia is an excellent testbed for new digital technologies, which is one of the seven strategic priorities of the National Digital Health Strategy.	• Fragmented service delivery, a lack of patient-focus and poor coordination between health silos are major barriers to integrated care, and reforms to address these barriers must include workforce readiness and training, integration of services, and interoperability of data and systems.[7] • The Australian health regulatory environment is becoming increasingly complex. There are more than 22,600 pages of combined state and federal legislation covering Australia's health sector, and up to 100 combined Commonwealth and state regulators.[357]	DECISION Leave Harvey Ball at 50% REASONS • Incremental policy preventing response to demands. • Data interoperability and privacy. • State and federal regulations are not aligned, fragmented in how they connect. • Data sharing between regional and urban environments. • Private hospitals want government to pay for putting public patients in private hospital beds. • Coordinated care is required.	◑



Appendix B

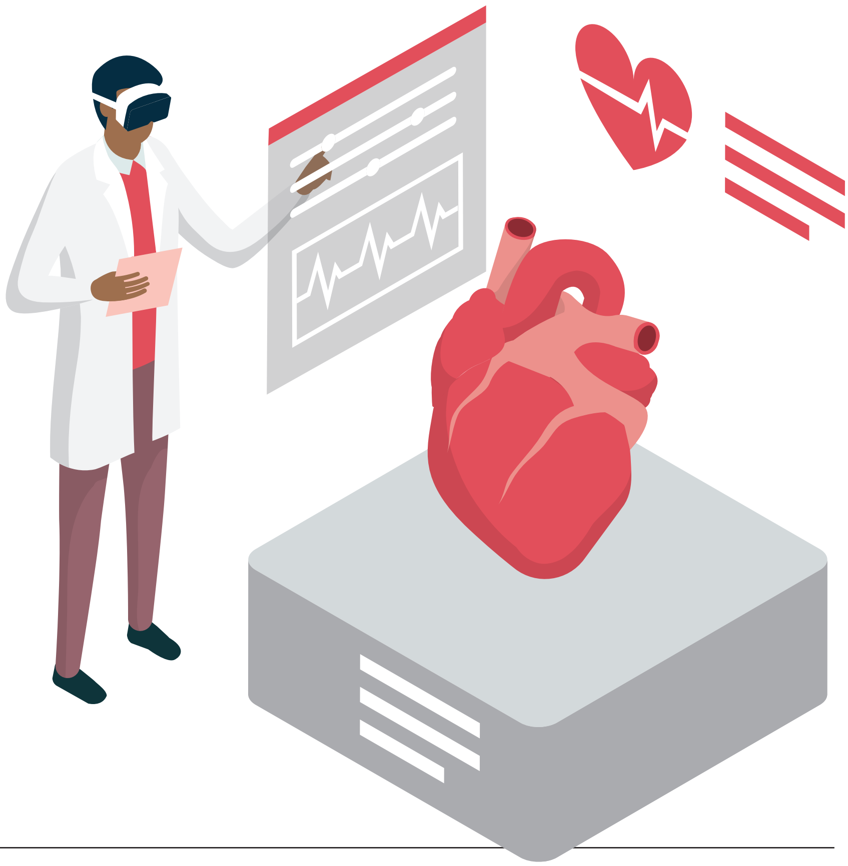
SUMMARY OF RESEARCH PRIORITY PROPOSALS

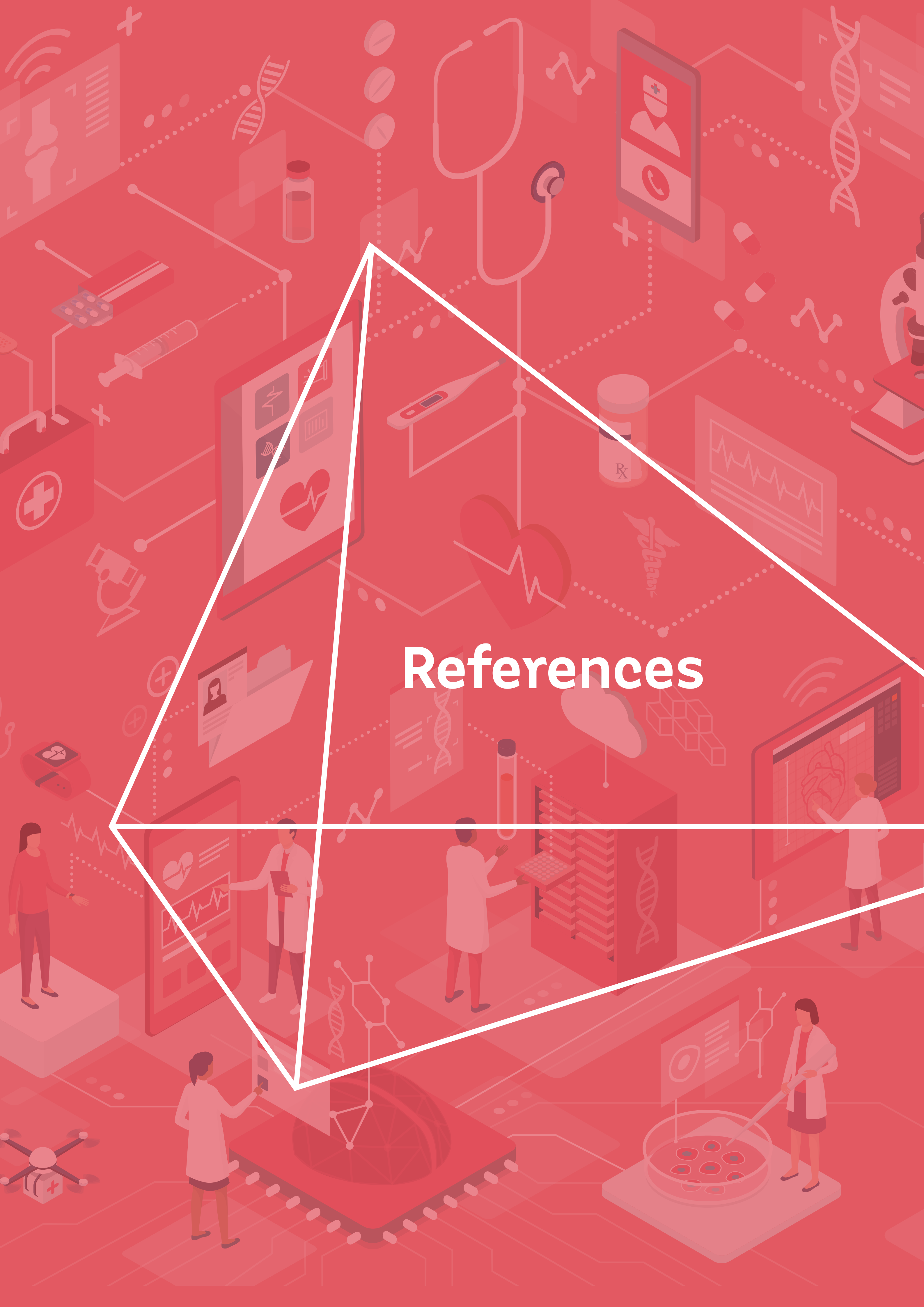
Australia's health system must prepare to integrate new technologies as part of the shift towards prevention and wellness. The four main issues identified by ATSE as major challenges facing Australia's healthcare system in this transition are digitisation, equity of access, workforce capability and commercialisation of MedTech research.

Australia has a strong research sector, with significant expertise, experience and capacity to investigate and develop best practice solutions to Australia's biggest challenges. For this reason, ATSE has identified a number of research priorities which would meet research needs and evidence gaps identified in this report. The following research priorities (Table 19) were identified during ATSE's consultations as important for successful adoption and integration of new health technologies by the health system and the wider community.

TABLE 19
Stakeholder identified research priorities by potential solution

DIGITAL & DATA	PRECISION MEDICINE	INTEGRATED CARE
Stakeholders identified that integrating new technology into the health system will be a challenge, and that cost, feasibility and value from new technology must be considered. Ensuring the smooth integration of technologies into the workflow was a priority for stakeholders, as digital tools become increasingly sophisticated. Research into improving our capabilities in data analysis, management and access for research purposes were also identified as priorities, along with the integration of AI and the management of poor quality data.	Stakeholders indicated the importance of determining best practice in precision medicine, and the growing volume of health data should be used to improve prevention and wellness at a population level and reduce healthcare costs through early detection and diagnosis. Stakeholders identified the potential of genomics and AI in health as valuable diagnostic tools in precision medicine.	Research into the benefits of technology enabled health was identified by stakeholders as a research priority, including mobile health and big health data, and to investigate the scalability of these technologies in order to reach the whole population. Stakeholders also identified that determining the value of self-monitoring technology such as wearables in improving health outcomes was also identified as a research priority. Stakeholders indicated that research into funding models that enable technology transformation may be necessary, to support the integration of new technology.





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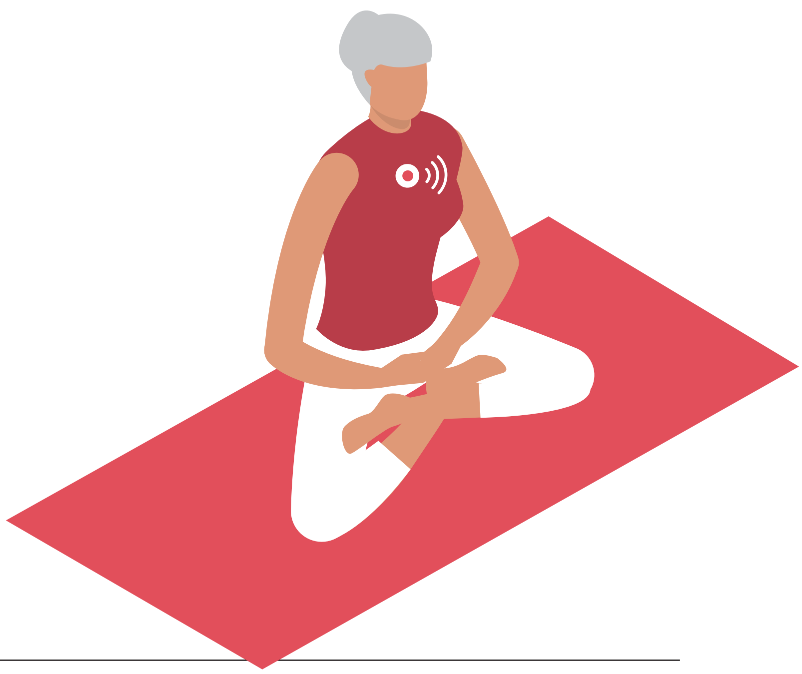

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Australian Academy of Technology & Engineering
info@atse.org.au
T. +61 3 9864 0900

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