CENTRE OF RESEARCH EXCELLENCE
REDUCING HEALTHCARE ASSOCIATED INFECTIONS

QUT

Research Outcomes Centre of Research Excellence in Reducing Healthcare Associated Infections

2012-2017

CONTENTS

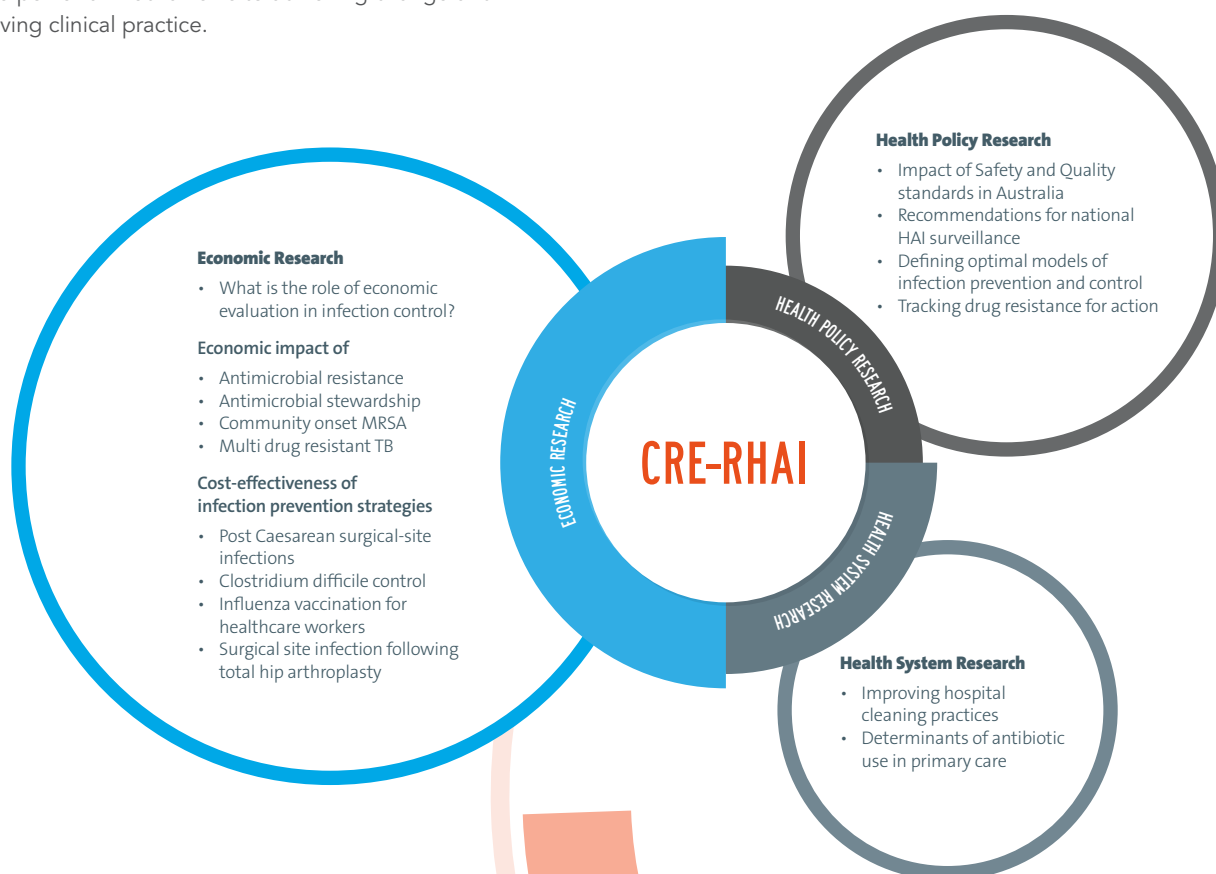# FOREWORD - PROFESSOR MARILYN CRUICKSHANK

Patients anticipate safe, high-quality healthcare and their expectations are generally fulfilled. However, far too many patients acquire an infection during their encounter with the health system. The growth of multi-resistant organisms within the health system highlights the need for research which is pragmatic and conducted in collaboration with decision makers and clinicians.

There are many strategies available for health systems to reduce infections involving systematic, national responses to infection control, surveillance, hand hygiene and antibiotic stewardship. None of these on their own can successfully achieve the outcomes that consumers, patients, clinicians and policy makers expect of the health system. Improvements in technology and leadership at all levels of the health system can be powerful mechanisms to achieving change and improving clinical practice.

Challenges to improvement are many; and not least is our ability to provide randomised, controlled evidence for all our practice. Also a challenge is the gathering of infection data and with trialling initiatives in infection prevention and control. Funding from the National Health and Medical Research Council of the CRE-RHAI in 2012 has meant a giant step in generating new knowledge and strategies to reduce healthcare associated infections. Together with data on the cost-effectiveness of infection control programs and interventions, policy makers and clinicians are better informed. Bringing together policy makers and clinicians, researchers are able to better contribute to successful implementation of change management programs in reducing infections, based on evidence produced in Australia.

The Australasian College for Infection Prevention and Control welcomes the breadth of research projects undertaken through the CRE-RHAI which provides the infection control healthcare community in Australia with a host of data and initiatives. We congratulate the students, their supervisors, and associated advisers who have made this work possible and brought the work to fruition. We look forward to subsequent stages of research based on these projects, and a community of experienced infection prevention and control oriented researchers.

Professor Marilyn Cruickshank RN PhD FACN CICP-E
PRESIDENT
Australasian College for Infection Prevention and Control

Economic Research

- What is the role of economic evaluation in infection control?

Economic impact of

- Antimicrobial resistance
- Antimicrobial stewardship
- Community onset MRSA
- Multi drug resistant TB

Cost-effectiveness of infection prevention strategies

- Post Caesarean surgical-site infections
- Clostridium difficile control
- Influenza vaccination for healthcare workers
- Surgical site infection following total hip arthroplasty

Health Policy Research

- Impact of Safety and Quality standards in Australia
- Recommendations for national HAI surveillance
- Defining optimal models of infection prevention and control
- Tracking drug resistance for action

Health System Research

- Improving hospital cleaning practices
- Determinants of antibiotic use in primary care

ECONOMIC RESEARCH
HEALTH POLICY RESEARCH
HEALTH SYSTEM RESEARCH
CRE-RHAI

EXECUTIVE STATEMENT AND RESEARCH SUMMARY PROFESSOR NICHOLAS GRAVES

All around the world healthcare associated infections are a major problem for patient safety and for national health systems. In Australia it has been known that surveillance of infection is the cornerstone of infection prevention in a healthcare setting for the last three decades. However, unlike in Europe and the US, Australia has not begun a national surveillance system to collect and report data on hospital acquired infections and it is now one of the few developed OECD countries to not be recording this data. The lack of this data has meant that Australia has not been able to robustly estimate or track the incidence of HAI in Australia or the costs to the healthcare system. The absence of sufficient information continues to limit the ability of policy makers to respond to emergency threats in the context of infection control.

The infection control healthcare community in Australia has long been concerned with gathering this data and with trialling initiatives in infection prevention and control. In line with this aim the CRE-RHAI was founded in 2012 with a grant from the National Health and Medical Research Council (NHMRC) in order to generate new knowledge about strategies to reduce healthcare associated infections as well as to provide data on the cost-effectiveness of infection control programs and interventions – data which could then influence decision making.

The projects undertaken have generated a body of evidence that will guide policy and practice, as well as focusing future research endeavors. They have all clearly demonstrated that health services research is most effective when it is pragmatic and conducted in collaboration with decision makers and clinicians. The research has – frequently – highlighted the need for greater surveillance in hospitals to collect better and more longitudinal data with which to measure infection control.

It has revealed the challenge of providing valuable and clearly communicable economic evaluations and providing this effectively to decision-makers. Finally, work produced (often in partnership with other organisations) has highlighted the need for health economists to really get involved in this area and to engage with policymakers, healthcare professionals and the community.

ANTIMICROBIAL USE AND RESISTANCE

Costs of Antimicrobial Resistance
One of the CRE-RHAI's most important results came from the investigation led by Dr Teresa Wozniak on the cost impact of antimicrobial resistance on bloodstream, urinary and respiratory tract infections in Australian hospitals. The data available demonstrated that in 2014 the Australian healthcare system spent an additional $16.8m treating patients with five key drug-resistant infections and lost an approximate $2.6m in funds that could have been spent on other activities.

Value for Money of Antimicrobial Stewardship in Hospitals
The CRE-RHAI also undertook the first cost-effectiveness analysis of Antimicrobial Stewardship (AMS) Interventions in Australia. This work, led by Dr Sonali Coulter, focused on how public hospitals in QLD could overcome problems with antimicrobial overuse, and improve outcomes for patients with serious infections. It identified that AMS interventions - which are reported to lead to a reduction of antimicrobial consumption by some 22-36% in the US - do also work in Australia and that such programs are therefore worth the monetary investment.

Tracking drug-resistant infections
Work supported by the CRE-RHAI also produced the first Australian prevalence-based model able to track the health and economic impact of drug-resistant infections in Australia. Unfortunately, two of the most prevalent resistant infections were not captured in the model's cost-estimate due to lack of data - and so further research is recommended.

Antibiotic use in Primary Care
Dr Elaine Lum's research ensured that the CRE-RHAI was responsive not only to issues within hospitals, but also to issues within the primary care sector. Dr Lum's work identified what expectations patients have about antibiotics when they see their General Practitioner (GP), and what factors influence whether GPs choose to prescribe antibiotics. Dr Lum also identified the important role that community pharmacists can play in reducing inappropriate antibiotic use, but cautioned that pharmacists in the community are under-utilised and must be empowered to act as antibiotic stewards.

BUNDLED APPROACHES TO HAI INTERVENTIONS

Improving the way hospitals are cleaned

Dr Michelle Allen led the 'PITCH' project – Preventing Infections Through Cleaner Hospitals. The project demonstrated the importance of involving non-clinical staff in infection prevention programs as well as how using implementation science in the healthcare system could improve the speed and extent of the translation of evidence into practice. It became the basis for a national, randomised controlled trial of an environmental hygiene bundle at 11 hospitals, which concluded in mid-2018.

Reducing Clostridium difficile (C.diff) Infections

Dr David Brain modelled the costs and effects of strategies to reduce C. diff infections. In a similar way to the PITCH project, a bundle of interventions (rather than one strategy alone) was proven to be the most effective and cost-effective way to reduce the occurrence of C. diff in hospitals. The research concluded that the cost of using the bundle of 'best practice' approaches in a new hospital was comparable to the treatment costs of common HAIs and less expensive than the purchase of newer, non-touch technologies.

Preventing surgical site infection after Caesarean-section

Dr Elizabeth Martin's research has focused on identifying current infection prevention practices among Australian obstetric surgeons and on determining the most cost-effective way of preventing such infections. The research has shown that a bundle of strategies, implemented together, will provide the best value for money approach to preventing surgical site infections for women giving birth via caesarean section. The research also identified that surveillance of post-caesarean surgical site infections in Australia is limited and poorly coordinated, impacting on researchers' abilities to provide evidence to improve practice.

OPTIMISING HAI PRACTICE AND POLICY

Surveillance

To examine the existing HAI surveillance activities across Australia, looking at the characteristics of international surveillance programs to identify enablers and barriers to implementing similar schemes in Australia, Dr Philip Russo conducted a national survey of healthcare employees and this revealed a very broad variation in HAI surveillance practices across the country. However, as well as finding a broad variation in practices Dr Russo's research discovered strong support among many stakeholders for nationally coordinated surveillance activities. The research suggested that having a centralised program with mandatory core elements, such as standardised basic risk adjustment, supported by training and regular competency assessment and public reporting, would result in high participation and acceptable data.

Best practice for statistical methods in research

Further research, led by Dr Xing Lee, examined what statistical methods should be used in infection-control research to best inform policy. Dr Lee's research suggested that more consideration should be given to microbiological surveillance of hospital environments.

Impact of Hospital Accreditation standards

Sally Havers' work into the 2010 introduction of the national Aseptic Technique practice and monitoring policy (in the framework of National Safety and Quality in Health Care standards) is ongoing. It is revealing powerful information about how Infection Control Practitioners implement policy changes in practice and about how to optimally resource such roles to ensure the highest standards of care in Australian hospitals.

Turning Research into Reality

Mindful that our economic focus is different from the approach taken in many infection control research groups, the CRE-RHAI supported Dr Greg Merlo to research how economic researchers can work with practitioners to ensure that the evidence generated is useful, useable, and translated into practice. Dr Merlo's work developed a framework for economic researchers in healthcare. It highlighted that engaging with policy makers, healthcare professionals and consumers is essential to ensuring good research outcomes and changes to policy and practice.

CONCLUSION

We are proud to have supported a range of research that has provided the Health Services community and specialist stakeholders with reliable data and with insights into the best methods for future research. We consider that we have made a significant contribution to the bank of information - and especially to the amount of data available that is linked to economic evaluation.

We hope our work will inform second and third stages of research and that that research will be done in closer collaboration with practitioners to bring about practical, realistic change for policy and practice.

As a result of CRE-RHAI work over the last six years, Australia has better and more widespread data about the factors that influence healthcare infection and is therefore closer to being able to monitor the problem at a national level.

Professor Nicholas Graves PhD
Professor of Health Economics
Chief Investigator and Academic Director, Centre of Research Excellence in Reducing Healthcare Associated Infections
Australian Centre for Health Services Innovation (AusHSI)
Queensland University of Technology

HEALTH SYSTEM RESEARCH:

PREVENTING INFECTIONS THROUGH CLEANER HOSPITALS

CONTEXT

Good hospital hygiene is known to reduce environmental contamination and the risk for transmission of healthcare-associated infections. Although general environmental cleanliness has been fostered in hospitals for over a century, the science of hospital hygiene is in its infancy, and preventable risks remain for patients. There are currently no accepted, risk-based standards to verify whether a hospital is truly clean and safe.

In Australia, while many hospitals have good infection control practices, research about the role cleaning plays in preventing infections is limited. Numerous cleaning standards and guidelines exist, but translating this information into meaningful, sustained improvements in cleaning practice is challenging.

RESEARCH

The CRE-RHAI supported research into an environmental cleaning bundle that might reduce the risk of healthcare-associated infections (HAIs) by improving the environmental cleanliness of a hospital.

The research was essentially a pilot study, trialling a tailored, hospital-specific, multi-part solution to perceived knowledge gaps in cleaning standards and consistency. The trial bundle had five core components:

- a demonstration (to staff) of the appropriate use of cleaning products (where and when to use disinfectant/detergent, correct concentration and contact time)

- training on cleaning techniques (focusing on frequent touch points and the physical motion and pressure used)

- a demonstration about how to use a UV marker to audit cleaning practices and give direct feedback to staff

- communication between clinical and environmental services staff, including talking about the importance of hospital-wide promotion and evaluation of cleanliness

- training for all environmental services staff on general infection prevention and the bundle components.

The project used structured on-site discussions with a standardised template to review hospital practices, as well as a document review of policy and procedural documents related to cleaning.

OUTCOMES

The project clearly identified best practices for cleaning hospitals. It found that implementing the bundle led to a statistically significant improvement in cleaning performance with the average proportion of clean surfaces (measured by UV markers) rising from 61.1% to 97.4%. Half of the intervention period observed hospital averages over 90% clean, with the odds of a clean result 14.25 times greater at the end of the intervention than at the baseline.

The bundle also led to improvements in environmental services workers' knowledge and attitudes, including the correct use of cleaning products, defined roles and responsibilities, better communication on the wards, and overall job satisfaction.

The research concluded that the incremental cost for repeating this process in a new hospital was comparable to the treatment costs of a common HAI, and less expensive than the purchase of newer non-touch technologies. It also indicated that the engagement of environmental services workers, targeted training and communication, active facilitation with internal and external change agents, and addressing social barriers were major factors contributing to the bundle's implementation success.

The project revealed that an environmental hygiene bundle is an effective mechanism to improve hospital hygiene, with demonstrated improvements in knowledge, attitudes and performance of environmental services workers, and a potentially reduced risk of transmission of HAIs.

Findings from the pilot study were used to refine the design of the cleaning bundle and its implementation strategies. The refined bundle became part of the REACH trial in 2016–2017, in which 11 major hospitals received tailored training and support from the study team to implement and evaluate the cleaning bundle intervention.

ANTIBIOTIC USE AND RESISTANCE IN PRIMARY CARE

CONTEXT

Antibiotic use drives antimicrobial resistance (AMR), a global issue with significant human health risk and economic burden. Australia is contributing to the global problem of AMR, with one of the highest rates of antibiotic use, ranking ninth amongst 26 OECD countries in the 2011 Health at a Glance report, dropping to 11th in 2015.

AMR is complex, intractable and costly in terms of its significant health burden and costs to individuals and to society. In Australia, it is estimated that AMR adds over $250m per year to the healthcare budget and costs the community another $500m per year.

AMR cannot be eradicated, only managed. Management of this issue in hospitals is through antimicrobial stewardship programs that optimise the appropriate use of antibiotics, improve patient outcomes and reduce unwanted effects such as toxicity and unnecessary costs.

In the Australian primary healthcare sector, where over 27 million prescriptions for antibiotics are written annually, data from general practice suggests unnecessary antibiotics are being prescribed for conditions that will resolve without them. These figures have since increased. Reports show that 30 million antibiotic prescriptions were dispensed in 2014 alone and that more than 50% of people with colds and other upper respiratory tract infections were prescribed an antibiotic unnecessarily.

A growing number of infections – such as pneumonia, tuberculosis and gonorrhea – are becoming harder to treat as the antibiotics used to treat them become less effective. However, the factors most important for driving antibiotic use in Australian primary healthcare have remained unclear.

RESEARCH

CRE-RHAI supported a research project to inform the implementation of Australia's national antimicrobial resistance strategy.

The project investigated the main factors influencing decisions to use antibiotics by general practitioners, community pharmacists and consumers in Australia. It posed two questions:

- What influences antibiotic use from the perspectives of general practitioners, community pharmacists, and consumers?
- How do general practitioners and consumers trade off on factors influencing antibiotic use?

OUTCOMES

This project quantified the preferences for decision-making in antibiotic prescribing and consumption. It confirmed and added to a base of evidence for action against antibiotic resistance.

Synthesising the findings from both the qualitative and quantitative components, the project reached a number of conclusions in terms of how to mitigate the over-prescription of antibiotics:

For general practitioners:

- patient expectations are an important – but surmountable – barrier
- medical colleagues' prescribing practices can pose a cultural challenge
- the uncertainty of diagnosis, coupled with patient expectations, exert prescribing pressure.

Community pharmacists are:

- an underused resource in mitigating antibiotic resistance
- disempowered to act as stewards of antibiotics.

For consumers to be engaged:

- patient education must address information needs
- public health campaigns on antibiotic awareness need to be seen by the target group
- campaigns need to translate into personal action.

The project concluded that the modifiable factors – patient expectations for antibiotics and general practitioner advice – are not only the two dominant factors, but are also mutually influencing factors for decision-making on antibiotic use, and should be leveraged.

Further, it recommended that the healthcare industry enact the Drug Utilisation Sub-Committee's proposed Pharmaceutical Benefit Scheme changes and leverage the power of consumers to influence GP's prescribing patterns.

Finally, it said that the role of community pharmacists is critical and that the industry should support the integration of community pharmacists into primary healthcare teams. Pharmacists are encouraged to seek out more information and training about their role in mitigating antibiotic resistance.

The project concluded that the government, policymakers and GPs – who have the authority, responsibility and resources to mitigate the rise of antibiotic resistance – must now step up their efforts.

HEALTH POLICY RESEARCH:

HOW TO INCREASE INFORMATION ABOUT AUSTRALIAN HAIs

CONTEXT

Healthcare-associated infections (HAIs) are one of the most common complications for patients in hospitals, yet Australia remains one of the few OECD countries to lack a national surveillance program.

The lack of current HAI data presents unreasonable challenges to those at a hospital, state and national level seeking evidence on which to base infection-prevention policy. It also severely limits local and national infection-prevention research initiatives. Importantly, it also raises doubts about patient safety and quality in infection prevention on a national scale.

RESEARCH

CRE-RHAI decided to support research into the gaps in existing HAI surveillance activities across Australia and explored the characteristics of international surveillance programs to identify enablers and barriers to implementing similar schemes in Australia.

OUTCOMES

There is broad variation in existing HAI-surveillance practices across Australia, meaning any attempt to collate existing data for a national aggregate would be flawed. Despite the lack of a national program, there is strong support amongst key stakeholders for nationally coordinated surveillance activities.

The research suggests having a centralised program with mandatory core elements – such as standardised basic risk adjustment, supported by training and regular competency assessment and public reporting – would result in high participation and acceptable data.

The project concluded that, to improve national patient safety and quality, Australia should develop and implement a national HAI-surveillance program.

THE IMPACT OF ACCREDITATION STANDARDS ON SAFETY AND QUALITY IN AUSTRALIAN HOSPITALS

CONTEXT

Infection control practitioners (ICPs) need to be responsive to health policy changes and regulatory requirements. However, researchers rarely investigate how this is achieved from both a practice and resource perspective.

In 2010, new infection-control policy requirements were introduced to all Australian hospitals regarding the practice and monitoring of the aseptic technique (AT), which minimises the risk of infection using the strictest rules to guide practices and procedures to prevent contamination from pathogens.

Although extensive literature and examination of the AT have been established in other countries, Australia lacks literature describing practices or investigating levels of compliance to the new policy requirements.

RESEARCH

The CRE-RHAI decided to support research with the aim of investigating the implementation of policy (particularly Infection Control Policy) in Australian hospitals, and the external and internal contextual factors that influence this process.

The project aimed to identify these factors and to develop a model of how they influence policy implementation at an organisational level. It set out to discover the perspectives of ICPs, asking what they were doing in relation to the introduction of the new infection control policy and identifying which factors commonly influenced their work.

ICPs from three Australian states were invited to participate in four focus groups in February of 2015. Purposeful sampling provided representation from public and private, regional and metropolitan services. All participants had been involved in implementation of AT policy in their hospitals. The questions put to the focus groups were based on the Consolidated Framework for Implementation Research and tried to identify which factors had influenced the implementation of the 2010 policy.

Researchers then analysed the focus group activity to determine key themes.

OUTCOMES

An analysis of the focus groups identified seven common themes that influenced policy implementation across organisations in Australia:

1. trigger/s for policy
2. resourcing and preparedness for implementation
3. skills and competency assessment
4. systems, processes and functionality (internal and external)
5. perceptions of policy and implementation process
6. roles and responsibilities
7. relationships and culture.

The project found that contextual factors do affect ICPs' implementation of national infection control policy in a variety of hospital settings and locations.

The project concluded that to improve the effectiveness of policy implementation, the industry should seek a better understanding of the issues for the benefit of policymakers, managers and clinicians.

THE IMPORTANCE OF APPROPRIATE STATISTICAL METHODS FOR INFECTION-CONTROL POLICY

CONTEXT

The process of methicillin-resistant Staphylococcus aureus (MRSA) transmission in hospital is difficult to represent accurately. This is due to the transient nature of patient and staff allocations, the typically small ward sizes and the incomplete nature of observed MRSA data (arising from the infeasibility of constantly monitoring the colonisation status of patients, staff and the ward environment).

The fundamental limitations of the data around infection transmission make accurate analysis difficult (which, in turn, makes policy decisions difficult).

It is therefore important for analysts to be fully cognizant of the data's limitations and to be able to appropriately quantify their sources in simulation modelling as well as in the final analysis.

RESEARCH

The CRE-RHAI supported research into MRSA transmission in a hospital ward setting. The research had a particular focus on quantifying the role of environmental contamination.

Importantly, the research used a combination of survival models and stochastic models as well as using Frequentist and Bayesian-based statistical inferential methods to quantify the relative contribution of microbiological environmental contamination to MRSA acquisition.

OUTCOMES

The research showed that hospital MRSA transmission is characterised by strong, random influxes and variation, but that it was possible to quantify the relative contribution of microbiological environmental contamination to MRSA acquisition with the right methods of analysis.

The project supported putting a greater emphasis on the use of appropriate statistical methods to analyse HAI data and associated patient outcomes. It also supported putting more consideration into a microbiological surveillance measure of hospital cleanliness.

It concluded that surveillance data is vital to validate and strengthen the evidence around the relative contribution of environmental contamination to MRSA acquisition in hospital, which in turn gives weight to infection-control policies and interventions.

ECONOMIC RESEARCH:

HOW TO TRANSLATE RESEARCH ABOUT COST-EFFECTIVENESS INTO PRACTICE

CONTEXT

The failure of evidence to translate into policy and practice is one of the most common findings in health services research.

Translating policy knowledge into a healthcare setting presents many difficulties, among them the fact that researchers and healthcare decision-makers have different incentives and norms, which can manifest as incompatible priorities. In addition, the fact that the academic sector likes to publish novel and rigorous research can be in contrast to healthcare management's more pragmatic need to make immediate decisions. Finally, the obscurity of academic language and the complexity of their methods can make translation challenging.

Some of the challenges to translating evidence-based research into practice are also specific to economic evaluation. For example, most healthcare professionals and managers do not have training in producing or interpreting economic evaluations and healthcare professionals have reported uncertainty about the methodological quality of economic evaluations. Sometimes, the topics addressed in economic evaluations do not meet the needs of healthcare professionals and policymakers, or the time it takes to complete an economic evaluation is longer than the time available to make a decision.

The translation of evidence from economic evaluations into healthcare practice has therefore not been widely successful. The CRE-RHAI wanted to understand whether or in what way healthcare professionals, administrators, and policymakers use cost-effectiveness research when translating infection-control programs into changes in health services.

RESEARCH

The research was structured to identify the barriers to using evidence from economic evaluations in healthcare decision-making and to systematically identify barriers and facilitators (using evidence from economic evaluations in healthcare policy and practice).

It developed a theoretical framework for the translation of evidence from economic evaluation into healthcare decision-making. The study mapped barriers and facilitators, using evidence from economic evaluations, onto the Consolidated Framework for Implementation Research in order to identify gaps, inconsistencies and emergent relations.

The project conducted a discrete choice experiment to examine the relative importance of a range of barriers and facilitators to using economic evaluations in healthcare decision-making. The study also conducted semi-structured interviews with health economists to learn from their experiences of translating economic evidence into healthcare policy and practice.

OUTCOMES

The importance of communication and engagement with stakeholders and clinical experts was a common theme in this research. Moreover, the project identified that certain methods of presenting evidence were less effective than others.

Healthcare decision-makers preferred to receive good quality economic evaluations that were specifically applicable and communicated well by independent researchers. They valued high methodological rigor and timeliness; however, they were willing to wait for an evaluation that was high quality in terms of modelling, clinical evidence used, and communication.

The project found that to translate evidence from economic evaluation into the healthcare process, it is necessary (at each stage) to find the correct balance between credibility, accessibility, and relevance – taking into account the inner and outer setting, and knowledge and attitudes of the decision-makers. It showed that it is important for decision-makers to receive information tailored to their needs and agendas.

The project demonstrated that health economists must actively engage with policymakers, healthcare professionals, and the community in order to maximise economic evaluation's impact on policy. It proved that if health economists formed closer relationships with decision-makers, they were more likely to be able to translate their work into practice. It provided an evidence basis to develop guidelines for translating evidence from economic evaluation into healthcare policy and practice. Finally, it concluded that health economists need best-practice implementation guidelines in order to make their research accessible and translatable into healthcare policy and practice. It recommended that health economists engage with policymakers, healthcare professionals and the community; communicate findings in a mode and manner appropriate to the audience; and advocate for the best-practice use of economic evaluation in healthcare decision-making.

CLOSTRIDIUM DIFFICILE BACTERIA: THE ECONOMICS OF INFECTION AND CONTROL

CONTEXT

Clostridium difficile is an anaerobic, gram-positive bacterium, known to be the foremost cause of in-hospital infectious diarrhea.

Almost all cases follow the use of antibiotics, and infection leads to longer hospital stays and worse health outcomes. The incidence of infection has risen in the last decade and there is an emerging evidence base about the epidemiology of the infection in Australia.

Until recently, there were no published papers about the economics of the infection and, in particular, no papers looking at the cost-effectiveness of potential control programs – and yet there is an increased expectation that healthcare providers will reduce the occurrence of infection.

RESEARCH

CRE-RHAI supported a research project that provided decision-makers with information about the management of Clostridium difficile that would help them balance the increasing demand for services with a finite budget.

The project used a model-based economic evaluation to identify the most cost-effective healthcare intervention relating to the reduction of Clostridium difficile transmission.

The evaluation included stand-alone interventions, such as antimicrobial stewardship (AMS), fecal microbiota transplantation (FMT), and reducing patient length of stay (LOS). The following bundled interventions, where practical combinations were coupled together, were also included: hygiene improvement (hand hygiene and environmental cleaning), hygiene improvement and AMS, hygiene improvement and FMT, reducing LOS and AMS, and reducing LOS and hygiene improvement.

The evaluation assessed which interventions might be relevant to reduce the incidence of Clostridium difficile alongside their respective costs, and assessed which would be the most cost-effective approach to managing infection.

The economic model used results from the most up-to-date and realistic mathematical transmission model for Clostridium difficile to assess possible healthcare interventions. A thorough costing analysis was also undertaken to inform the model's parameters and ensure the research objectives were met.

OUTCOMES

The study found that the best and most cost-effective way to improve hospital hygiene – and reduce the occurrence of Clostridium difficile – was by implementing a hand hygiene and environmental cleaning bundle.

It found that compared to standard care, seven of the ten infection control interventions resulted in health gains and cost savings. A bundled approach of improving hand hygiene and environmental cleaning together produced the best combination of increased health benefits and cost savings (including cost savings of approximately $2.2m).

The research confirmed current infection control wisdom by finding that there is an economic benefit to implementing infection control interventions in bundles rather than as stand-alone interventions and so should be used to inform improvements in the management of Clostridium difficile infection.

COST-EFFECTIVENESS OF NEW DIAGNOSTIC TECHNOLOGY FOR TUBERCULOSIS

CONTEXT

The emergence of drug-resistant tuberculosis (TB) poses a threat to the goal of worldwide elimination of the disease. While Australia has a relatively low TB burden, it is one of the few countries that has recently experienced an increase in the incidence of the disease.

Drug-resistant TB is strikingly high in Queensland's nearest geographic neighbour, Papua New Guinea, where an estimated 3.4% of new TB cases and 26% of previously treated TB cases are classified as drug-resistant. Since Australia and Papua New Guinea have a policy of relatively free movement of people across the Torres Strait for cultural reasons, there is an increased risk of transmission of drug-resistant TB in Queensland.

A new nucleic acid amplification test (GeneXpert) is now available and can rapidly diagnose whether a person is infected with the tuberculosis mycobacterium and whether the particular strain of TB is resistant to rifampicin – a major anti-tuberculosis drug. The test gives results within a few hours as opposed to traditional methods of drug-sensitivity testing, which can take up to six weeks.

Using these new rapid diagnostics avoids the risk of doctors prescribing ineffective drug therapy to patients with drug-resistant strains of TB, and so avoids charging for treatment and unnecessary isolation for patients who do not have TB (or drug-resistant TB). Other benefits of using it include faster initiation of contact tracing and, as a result, prevention of further TB transmission.

The GeneXpert device and consumables currently have a concessional pricing arrangement for use in "high-burden" countries, but Australia – as a "low-burden country" – does not have access to the concessional pricing. Consequently, GeneXpert testing is comparatively expensive. Identifying whether the deployment of new rapid diagnostic technologies in this context is cost-effective is important to ensure the continued efficient expenditure of limited health budgets.

RESEARCH

The CRE-RHAI decided to support a research project to look at whether the deployment of GeneXpert in Queensland is cost-effective (given its relatively low TB burden and the inability of Queensland health systems to access concessional pricing).

OUTCOMES

This study developed an epidemiological model that represents the different disease epidemiologies in Papua New Guinea and Australia. The model accounts for the rate of movement of people between the two countries, as well as improvements in diagnostic time due to new TB diagnostic technology, and how these factors might impact disease transmission and, ultimately, costs.

The project includes a detailed cost analysis of TB diagnosis and treatment in Queensland which, when complete, will provide evidence for a final cost-effectiveness evaluation.

THE ECONOMICS OF PREVENTING SURGICAL SITE INFECTION FOLLOWING CAESAREAN SECTION

CONTEXT

Surgical site infections following caesarean section are expensive and painful. However, clinicians do not know which prevention strategies are the most effective. The data around the incidence of surgical site infection is very poor in Australia as incidences of infection and the consequences of that infection often go unreported.

RESEARCH

The CRE-RHAI supported a research project to model the cost-effectiveness of adhering to best-practice perioperative and surgical strategies that prevent surgical site infection following caesarean section.

An infection prevention bundle was developed to trial the strategies that are considered best practice:

- pre-incision antibiotic prophylaxis

- vaginal cleansing

- spontaneous placenta removal.

The research showed that only 4.5% of Australian obstetricians implemented the bundle; however, the reasons for low engagement remained unknown and were not necessarily a result of cost. The project considered that the best-available data informing the economic model remained questionable.

OUTCOMES

The results of this research could not directly inform decision-making for preventing surgical site infection following caesarean section. The project highlighted the dearth of good quality data, considering the data gathered was insufficient to fully inform economic modelling or outline priorities for future research.

However, the data was sufficient to support the following recommendations:

- health services should adopt the infection-prevention bundle for emergency caesarean sections only

- health professionals who currently implement the infection-prevention bundle should continue to do so

- surgical site infection surveillance for caesarean section should be conducted to better-inform future economic modelling.

COST-EFFECTIVENESS OF ANTIMICROBIAL STEWARDSHIP (AMS) INTERVENTIONS IN AUSTRALIAN HOSPITALS

CONTEXT

Use of antimicrobial agents to treat and prevent infections is an essential component of medical care. Indeed, many advances in critical care medicine, surgery and transplantation would not be possible without the use of effective antimicrobials. While antimicrobials benefit the individual patient, the emergence of resistance has consequences to all of society. In 2014, the World Health Organization (WHO) urged all countries to work together to improve surveillance and to address the issue of antimicrobial resistance.

An effective approach to improving antimicrobial use in hospitals may be achieved by an organised antimicrobial management program known as antimicrobial stewardship (AMS). The overarching goals of an AMS program are to optimise clinical outcomes while minimising the unintended consequences of antimicrobial use, including toxicity, the rise of opportunistic pathogens (such as Clostridium difficile), and the emergence of antimicrobial resistance.

AMS interventions have been reported to reduce antimicrobial consumption by 22–36% and lead to a cost reduction of US$200 000–900 000 per annum in some hospitals in the USA. Despite this, attracting adequate support for these activities has been reported as difficult, as AMS is competing for resources against many other healthcare initiatives.

The implementation of Antimicrobial Stewardship (AMS) in Australian hospitals is mandatory, but the components of each program are heterogeneous. Whilst there are many combinations of strategies available for the development of an AMS program, it is unclear which are optimal.

RESEARCH

The CRE-RHAI decided to support the first cost-effectiveness analysis of AMS interventions in Australia.

The project aimed to synthesise existing literature on the cost-effectiveness of AMS programs, assessing the cost and health outcomes, the economic evaluation methods used and the overall findings of this body of research, including important knowledge gaps in this area.

The project evaluated the cost-effectiveness of key AMS strategies – including the AMS team and the value of rapid diagnostics and Clinical Decision Support Systems (CDSS) – in the context of AMS interventions implemented at two metropolitan hospitals in Brisbane, Australia. It focused on how public hospitals in Queensland could overcome problems and improve outcomes for patients with serious infections.

OUTCOMES

The AMS interventions at both hospitals were cost-saving and resulted in modest positive net monetary value. Rapid pathogen identification provided value for money, but the impact of CDSS was less conclusive. The impact of labour costs in assembling an AMS team was also shown to have a major bearing on expenditure.

The research has highlighted a need to routinely collect better data on longer-term mortality and adverse outcomes for patients on antimicrobial therapy. It supports these conclusions:

- clinical decision makers should carefully consider which components of an AMS intervention best suit their setting to maximise cost saving

- to better evaluate the true cost-effectiveness of AMS, longitudinal patient outcome data needs to be more rigorously and routinely collected.

THE ECONOMIC BURDEN OF ANTIMICROBIAL RESISTANCE IN AUSTRALIAN HOSPITALS

CONTEXT

Antimicrobial resistance (AMR) of gram-negative bacilli is a global threat, but little is known of the health and economic impact at a country-level in Australia.

Given the global spread of the resistance, it is important to understand the Australia-specific epidemiology and the consequent costs that drug-resistant infections have on health and the healthcare system.

Gathering this data is useful to develop healthcare policy and planning, prioritise resources and implement evidence-based practice.

RESEARCH

The CRE-RHAI supported a research project that assessed the impact of antimicrobial resistance on bloodstream, urinary and respiratory tract infections in Australian hospitals with the aim of understanding the economic burden on key gram-negative antimicrobial resistant infections.

The research aimed to promote evidence-based methods, facilitate decision-making prioritisation, identify gaps in surveillance data, and provide a comprehensive framework for communicating complex information to decision-makers.

OUTCOMES

The research produced the first Australian prevalence-based model (termed Health and Economic Modelling of Antimicrobial resistance in Australia, or HEMAA) able to track the health and economic impact of drug-resistant infections in Australia. The model is flexible, evidence-based and transparent. When accompanied with the online, open-access tool (ResImpact), it can be updated and used to derive longitudinal cost estimates of drug-resistant infections in Australia.

The model was then able to provide the first Australian-based data estimate of the cost of resistance in Australia for five key organisms, with a baseline estimate for 2014 that included the following important findings:

- In 2014, the Australian healthcare system spent an additional estimated $16.8m on five key drug-resistant infections (E. coli, K. pneumonia, P. aeruginosa, E. faecium and S. aureus) and lost an approximate $2.6m in funds that could have been spent on other critical activities such as freeing up a bed for alternative use.

- Vancomycin-resistant E. faecium bloodstream infections cost an estimated $10,682 per infection, followed closely by ceftriaxone-resistant E. coli. However, due to the high prevalence of E. coli and the attributable length of hospital stay, the largest contributor to the overall costs of drug resistant infections in 2014 was ceftriaxone resistant E. coli, costing a total of $5.8m per year over and above the cost of susceptible infections.

As well as evaluating the costs of antimicrobial resistance in Australia, the research also identified significant knowledge gaps in terms of the understanding of the epidemiology and the health impact of drug-resistant infections.

Unfortunately, two of the most prevalent resistant infections, namely resistant E. coli urinary tract infections and P. aeruginosa respiratory infection, were not captured in the model's cost estimates due to lack of data.

This research project supports the recommendation that it is important to promote evidence-based processes to better understand the impact of AMR. Specifically, the Australian healthcare system should enact the following:

- make better use of available data on the health and economic impact of AMR
- develop standard methodologies to collect new data on the health impact of AMR
- facilitate planning and improve communication between data analysts/researchers and end-users
- better understand the needs of AMR policymakers and how collaborative partnerships could support these needs
- develop user-friendly tools to better communicate research.

CO-MRSA COSTS $450M ANNUALLY IN AUSTRALIA

CONTEXT

Community-onset methicillin-resistant Staphylococcus aureus (CO-MRSA) imposes a significant burden on Australian society. The number of cases and the costs associated with skin and soft tissue infections (SSTIs) in remote areas are particularly high. The disproportionate impact on Indigenous people living in those remote areas is an issue of severe inequality.

SSTIs in remote areas can lead to death, but bed occupancy accounts for the majority of costs to the health system. Accurately understanding the burden of CO-MRSA is crucial for developing policy, evidence-based practice, resource allocation and identifying opportunities for savings and prevention.

RESEARCH

Data on SSTIs in remote areas exists for only a fraction of Australians. The CRE-RHAI supported a research project that set out to estimate the health and economic burden of CO-MRSA by conducting an economic simulation, using data from literature to cost infections.

OUTCOMES

The research project was able to demonstrate that CO-MRSA costs society approximately $450m annually in Australia.

It supported the following recommendations:

- the need for broad-scale surveillance with nationally consistent definition
- the need to link pathology data sets and health records to further understanding of the outcomes associated with specific organisms
- the need to reduce the number of SSTIs that progress to sepsis and improve access to health hardware in remote areas to produce better health outcomes as well as significant savings.

CRE-RHAI CONCLUSION

These projects have generated a body of evidence that will guide policy and practice, as well as focusing future research endeavours. They have clearly demonstrated that health services research is most effective when it is pragmatic and conducted in collaboration with decision-makers and clinicians. The projects have frequently highlighted the need for surveillance in hospitals to collect better and more longitudinal data with which to measure infection control. Finally, they have revealed the challenge of providing valuable and clearly communicated economic evaluations to decision-makers, emphasising the need for health economists to engage with policymakers, healthcare professionals, and the community.

For further information, please contact Chief Investigator, Professor Nicholas Graves, **n.graves@qut.edu.au or contact@aushsi.org.au**

PEER-REVIEWED PUBLICATIONS FROM THE CRE-RHAI

1. Allen, M., L. Hall, K. Halton, and N. Graves, *Improving hospital environmental hygiene with the use of a targeted multi-modal bundle strategy.* Infection, Disease and Health, 2018. 23(2): p. 107-13.

2. Brain, D., L. Yakob, A. Barnett, T. Riley, A. Clements, K. Halton, and N. Graves, *Economic evaluation of interventions designed to reduce Clostridium difficile infection.* PLoS ONE, 2018. 13(1).

3. Brain, D.C., A.G. Barnett, L. Yakob, A. Clements, T.V. Riley, K. Halton, and N. Graves, *Reducing length of stay to improve Clostridium difficile-related health outcomes.* Infection, Disease and Health, 2018. 23(2): p. 87-92.

4. Graves, N., *The Centre of Research Excellence in Reducing Healthcare Associated Infections.* Infection, Disease and Health, 2018. In press.

5. Lee, X.J., A.N. Pettitt, and S.J. Dancer, *Quantifying the relative effect of environmental contamination on surgical ward MRSA incidence: An exploratory analysis.* Infection, Disease & Health, 2018.

6. Lum, E.P.M., K. Page, J.A. Whitty, J. Doust, and N. Graves, *Antibiotic prescribing in primary healthcare: Dominant factors and trade-offs in decision-making.* Infection, Disease and Health, 2018. 23(2): p. 74-86.

7. Martin, E., M. Beckmann, L. Barnsbee, K. Halton, K. Merollini, and N. Graves, *Best practice perioperative strategies and surgical techniques for preventing caesarean section surgical site infections: A systematic review of reviews and meta-analyses.* BJOG: An International Journal of Obstetrics and Gynaecology, 2018. 125(8): p. 956-64.

8. Mitchell, B.G., N. White, A. Farrington, M. Allen, K. Page, A. Gardner, K. Halton, T.V. Riley, C.A. Gericke, D.L. Paterson, N. Graves, and L. Hall, *Changes in knowledge and attitudes of hospital environmental services staff: The Researching Effective Approaches to Cleaning in Hospitals (REACH) study.* Am J Infect Control, 2018.

9. Wozniak, T.M., *Clinical management of drug-resistant bacteria in Australian hospitals: An online survey of doctors' opinions.* Infection, Disease & Health, 2018. 23(1): p. 41-48.

10. Wozniak, T.M., N. Graves, and A.G. Barnett, *How much do superbugs cost Australian hospitals? An evidence-based open-access tool.* Infection, Disease & Health, 2018. 23(1): p. 54-6.

11. Coulter, S., J.A. Roberts, K. Hajkowicz, and K. Halton, *The Use of Bloodstream Infection Mortality to Measure the Impact of Antimicrobial Stewardship Interventions: Assessing the Evidence.* Infect Dis Rep, 2017. 9(1): p. 6849.

12. Halton, K., L. Hall, A. Gardner, D. MacBeth, and B.G. Mitchell, *Exploring the context for effective clinical governance in infection control.* Am J Infect Control, 2017. 45(3): p. 278-283.

13. Havers, S.M., P.L. Russo, K. Page, A. Wilson, and L. Hall, *Aseptic technique and the implementation of national policy: Contextual factors for consideration.* Infection, Disease & Health, 2017. 22(2): p. 94-95.

14. Lee, X.J., G.R. Fulford, A.N. Pettitt, and F. Ruggeri, *A stochastic model for MRSA transmission within a hospital ward incorporating environmental contamination.* Epidemiol Infect, 2017. 145(4): p. 825-838.

15. Lum, E.P.M., K. Page, L. Nissen, J. Doust, and N. Graves, *Australian consumer perspectives, attitudes and behaviours on antibiotic use and antibiotic resistance: a qualitative study with implications for public health policy and practice.* BMC Public Health, 2017. 17(1): p. 799.

16. Mitchell, B.G., D. MacBeth, K. Halton, A. Gardner, and L. Hall, *Resourcing hospital infection prevention and control units in Australia: A discussion paper.* Infection, Disease & Health, 2017. 22(2): p. 83-88.

17. Page, K., A.G. Barnett, and N. Graves, *What is a hospital bed day worth? A contingent valuation study of hospital Chief Executive Officers.* BMC Health Serv Res, 2017. 17(1): p. 137.

18. Russo, P.L., A.C. Cheng, B.G. Mitchell, and L. Hall, *Healthcare-associated infections in Australia: tackling the 'known unknowns'.* Australian Health Review, 2017. 42: p. 178-180.

19. Wozniak, T.M., D. Paterson, and K. Halton, *Review of the epidemiological data regarding antimicrobial resistance in Gram-negative bacteria in Australia.* Infection, Disease & Health, 2017. 22(4): p. 210-218.

20. Graves, N., C. Wloch, J. Wilson, A. Barnett, A. Sutton, N. Cooper, K. Merollini, V. McCreanor, Q. Cheng, E. Burn, T. Lamagni, and A. Charlett, *A cost-effectiveness modelling study of strategies to reduce risk of infection following primary hip replacement based on a systematic review.* Health Technol Assess, 2016. 20(54): p. 1-144.

21. Hall, L., A. Farrington, B.G. Mitchell, A.G. Barnett, K. Halton, M. Allen, K. Page, A. Gardner, S. Havers, E. Bailey, S.J. Dancer, T.V. Riley, C.A. Gericke, D.L. Paterson, and N. Graves, *Researching effective approaches to cleaning in hospitals: Protocol of the REACH study, a multi-site stepped-wedge randomised trial.* Implementation Science, 2016. 11(1).

22. Merlo, G., N. Graves, D. Brain, and L. Connelly, *Economic Evaluation of Fecal Microbiota Transplantation for the Treatment of Recurrent Clostridium Difficile Infection in Australia.* J Gastroenterol Hepatol, 2016. 31(12): p. 1927-32.

23. Russo, P.L., G. Chen, A.C. Cheng, M. Richards, N. Graves, J. Ratcliffe, and L. Hall, *Novel application of a discrete choice experiment to identify preferences for a national healthcare-associated infection surveillance programme: a cross-sectional study.* BMJ Open, 2016. 6(5): p. e011397.

24. Russo, P.L., S.M. Havers, A.C. Cheng, M. Richards, N. Graves, and L. Hall, *Characteristics of national and statewide health care-associated infection surveillance programs: A qualitative study.* Am J Infect Control, 2016. 44(12): p. 1505-1510.

25. Coulter, S., K. Merollini, J.A. Roberts, N. Graves, and K. Halton, *The need for cost-effectiveness analyses of antimicrobial stewardship programmes: A structured review.* International Journal of Antimicrobial Agents, 2015. 46(2): p. 140-149.

26. Hall, L., K. Halton, D. Macbeth, A. Gardner, and B. Mitchell, *Roles, responsibilities and scope of practice: describing the 'state of play' for infection control professionals in Australia and New Zealand.* Healthcare infection, 2015. 20(1): p. 29-35.

27. Havers, S.M., P.L. Russo, B. Mitchell, and L. Hall, *Health-care-associated infections.* The Lancet Infectious Diseases, 2015. 15(7): p. 763-764.

28. Lee, X.J., C.C. Drovandi, and A.N. Pettitt, *Model choice problems using approximate Bayesian computation with applications to pathogen transmission data sets.* Biometrics, 2015. 71(1): p. 198-207.

29. Martin, E., *Rationing in Healthcare.* 2015, Deeble Insitute - Issues Brief: Canberra.

30. Merlo, G., K. Page, J. Ratcliffe, K. Halton, and N. Graves, *Bridging the Gap: Exploring the Barriers to Using Economic Evidence in Healthcare Decision Making and Strategies for Improving Uptake.* Applied Health Economics and Health Policy, 2015. 13(3): p. 303-309.

31. Mitchell, B.G., L. Hall, K. Halton, D. MacBeth, and A. Gardner, *Infection control standards and credentialing.* Am J Infect Control, 2015. 43(12): p. 1380-1.

32. Mitchell, B.G., L. Hall, D. MacBeth, A. Gardner, and K. Halton, *Hospital infection control units: staffing, costs, and priorities.* Am J Infect Control, 2015. 43(6): p. 612-6.

33. Russo, P.L., A.G. Barnett, A.C. Cheng, M. Richards, N. Graves, and L. Hall, *Differences in identifying healthcare associated infections using clinical vignettes and the influence of respondent characteristics: A cross-sectional survey of Australian infection prevention staff.* Antimicrobial Resistance and Infection Control, 2015. 4(1).

34. Russo, P.L., A.C. Cheng, M. Richards, N. Graves, and L. Hall, *Variation in health care-associated infection surveillance practices in Australia.* American Journal of Infection Control, 2015. 43(7): p. 773-775.

35. Russo, P.L., A.C. Cheng, M. Richards, N. Graves, and L. Hall, *Healthcare-associated infections in Australia: Time for national surveillance.* Australian Health Review, 2015. 39(1): p. 37-43.

36. Allen, M., K. Halton, L. Hall, E. Bailey, and N. Graves, *Preventing infections through cleaner hospitals project.* Aust Nurs Midwifery J, 2014. 22(3): p. 32.

37. Avent, M.L., L. Hall, L. Davis, M. Allen, J.A. Roberts, S. Unwin, K.A. McIntosh, K. Thursky, K. Buising, and D.L. Paterson, *Antimicrobial stewardship activities: A survey of Queensland hospitals.* Australian Health Review, 2014. 38(5): p. 557-563.

38. Cooper, K., G. Frampton, P. Harris, J. Jones, T. Cooper, N. Graves, J. Cleland, J. Shepherd, A. Clegg, and B.H. Cuthbertson, *Are educational interventions to prevent catheter-related bloodstream infections in intensive care unit cost-effective? J Hosp Infect, 2014. 86(1): p. 47-52.

39. Graves, N., *The economics of UTI surveillance.* Healthcare Infection, 2014. 19(1): p. 37.

40. Graves, N., *How costs change with infection prevention efforts.* Curr Opin Infect Dis, 2014. 27(4): p. 390-3.

41. Halton, K., N. Graves, and L. Hall, *Opportunity cost of unavailable surgical instruments in Australian hospitals.* ANZ J Surg, 2014. 84(12): p. 905-6.

42. Martin, E., *Preventing infections following caesarean section.* Aust Nurs Midwifery J, 2014. 22(3): p. 37.

43. Mitchell, B.G., A. Gardner, A.G. Barnett, J.E. Hiller, and N. Graves, *The prolongation of length of stay because of Clostridium difficile infection.* Am J Infect Control, 2014. 42(2): p. 164-7.

44. Zheng, H., A.G. Barnett, K. Merollini, A. Sutton, N. Cooper, T. Berendt, J. Wilson, and N. Graves, *Control strategies to prevent total hip replacement-related infections: a systematic review and mixed treatment comparison.* BMJ open, 2014. 4(3): p. e003978.

45. Hall, L., K. Halton, E.J. Bailey, K. Page, M. Whitby, D.L. Paterson, and N. Graves, *Post-discharge surgical site surveillance - where to from here? J Hosp Infect, 2013. 84(3): p. 268.

46. Merollini, K.M.D., R.W. Crawford, and N. Graves, *Surgical treatment approaches and reimbursement costs of surgical site infections post hip arthroplasty in Australia: A retrospective analysis.* BMC Health Services Research, 2013. 13(1).

47. Merollini, K.M.D., R.W. Crawford, S.L. Whitehouse, and N. Graves, *Surgical site infection prevention following total hip arthroplasty in Australia: A cost-effectiveness analysis.* American Journal of Infection Control, 2013. 41(9): p. 803-809.

48. Merollini, K.M.D., H. Zheng, and N. Graves, *Most relevant strategies for preventing surgical site infection after total hip arthroplasty: Guideline recommendations and expert opinion.* American Journal of Infection Control, 2013. 41(3): p. 221-226.

49. Mitchell, B.G., S.J. Dancer, R.Z. Shaban, and N. Graves, *Moving forward with hospital cleaning.* American Journal of Infection Control, 2013. 41(11): p. 1138-1139.

50. Page, K., N. Graves, K. Halton, and A.G. Barnett, *Humans, 'things' and space: Costing hospital infection control interventions.* Journal of Hospital Infection, 2013. 84(3): p. 200-205.

51. Page, K., N. Graves, K. Halton, E.J. Bailey, G.R. Fulford, and M. Whitby, *Key priorities for Australian infection control: Summary of findings from the launch of the Centre for Research Excellence in Reducing Healthcare Associated Infections.* Healthcare Infection, 2012. 17(4): p. 133-135.

Theses (available on QUT e-prints)

1. Allen, Michelle. (2016) *Preventing infections through cleaner hospitals (PITCH)- A novel targeted hospital environmental hygiene bundle.* PhD thesis, Queensland University of Technology

2. Russo, Philip L. (2016) *Evidence based recommendations for national healthcare-associated infection surveillance.* PhD by Publication, Queensland University of Technology.

3. Brain, David C. (2016) *An economic evaluation of healthcare interventions designed to reduce Clostridium difficile infection.* PhD thesis, Queensland University of Technology.

4. Lum, Elaine P. (2017) *Making decisions about antibiotic use in the Australian primary healthcare sector.* PhD thesis, Queensland University of Technology.

5. Lee, Xing Ju (2017) *Statistical and simulation modelling for enhanced understanding of hospital pathogen and related health issues.* PhD by Publication, Queensland University of Technology.

6. Merlo, Gregory B. (2017) *"Going over the parapet": The development of a framework for understanding the translation of evidence from economic evaluations.* PhD thesis, Queensland University of Technology.

7. Martin, Elizabeth Kate (2017) *A cost-effectiveness modelling study of strategies to prevent post-caesarian surgical site infection.* PhD thesis, Queensland University of Technology.

8. Coulter, Sonali A. (2018) *An economic evaluation of antimicrobial stewardship programs in metropolitan Australian hospitals.* PhD thesis, Queensland University of Technology.

CENTRE OF RESEARCH EXCELLENCE
REDUCING HEALTHCARE
ASSOCIATED INFECTIONS

AusHSI

*Bringing health
innovation to life*

AUSTRALIAN CENTRE FOR
HEALTH SERVICES INNOVATION

www.aushsi.org.au

QUT ihbi Institute of Health
and Biomedical Innovation