Implementing echocardiographic screening for the early detection of rheumatic heart disease in remote First Nations Australian communities

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A thesis submitted for the degree of

Doctor of Philosophy

Hilary 2026

To my big brother, Lachlan.

Abstract

Rheumatic heart disease continues to cause substantial morbidity and mortality in remote First Nations communities in Australia, despite being largely eliminated in the rest of the country. Echocardiography allows for early detection and timely management to prevent disease progression, but access is often limited in high-burden settings. A task-sharing model of echocardiographic screening, whereby local healthcare staff are trained to use handheld devices to scan children's hearts, with remote cardiologist interpretation, has emerged as a promising, evidence-based means of improving access. However, optimal implementation remains unclear. This thesis aims to improve understanding of how echocardiographic screening for rheumatic heart disease can be implemented in remote First Nations communities.

The thesis begins with an overview of the topic in Chapter 1 and an outline of the methods in Chapter 2. This is followed by four original research chapters. Chapter 3 presents a narrative review of implementation lessons from a comparable screening programme and a scoping review of Theory of Change use in programme design and evaluation. Chapter 4 describes the co-design of implementation plans for an echocardiographic screening programme across five remote communities. Chapters 5 and 6 report the process evaluation and realist evaluation of the screening programme, respectively.

The results of this thesis draw on data collected across five remote sites, including 36 interviews, 39 surveys, seven focus groups, 200 researcher-days of observation, 360 scan records, costing data, and administrative data. These data indicated that the implementation of echocardiographic screening resulted in modest and variable activity with a site-level screening coverage of 3–85% of the eligible population. Fidelity to the original programme design was limited by unreliable device readiness, image upload failures, and delays in image review. Set-up and training cost AU$51,903 per site, plus approximately AU$9,858 per year for implementation support. Under the conditions observed across sites, embedding opportunistic screening into First Nations community health workers' routine practice was difficult. Successful embedding depended on the perceived legitimacy of the scanner role and on support for the invisible logistical and relational work required to scan. Event-based screening increased coverage, albeit at higher cost.

Overall, the findings support a hybrid approach that strengthens the conditions for opportunistic screening within facilities, complemented by periodic screening events with visiting sonographer support. Future research should explore policies, guidelines, and funding models that enable sustained screening and scale-up.

Acknowledgements

Amongst the spires of a place I never thought I would be, where colleagues and friends dream up solutions to the greatest challenges of our age, I am proud of making this small contribution to a corner of the world that feels important to me. I think my Ma, and all my ancestors, would be too.

A quarter of the way into the 21st century, as science fiction seems increasingly less like fiction, this thesis should feel anachronistic. Australia has an enduring contradiction at its core, and it manifests in preventable damage to the hearts of young people in remote First Nations communities. I want to acknowledge the people from these communities who I have worked with, and thank them for their time and their trust. They hold Australia with grace, in all its grit and glory.

Thank you to my supervisors. Mike, for showing me that honest, thoughtful research has a place, and that the relationships made are as important as the work. Shobi, for modelling the power of kindness in locally grounded research. Josh, for embodying what it means to not pretend to love others, but to really love them.

Thank you Jen and James, for being both mentors and friends. Thank you Alice and Aunty Vicki, your love for mob makes me believe in an Australia that could be. Thank you Meghan and the NEARER SCAN team, for working with hope and humility. Thank you to the Health Systems Collaborative, it has been a privilege to be part of a team that conducts research with such care and consideration.

Thank you Matt, for being as good of a friend from afar as you were when we were seeing off the new ball. Thank you Nick and Claire, for the constant nourishment of your friendship. Thank you Rhieve, Amy, KDee, and Marco, for sharing the wisdom of your Countries. Thank you Nanak, Kenza, Mudi, and Amar, for filling my days here with laughter and last minute plans. Thank you Bruce, Michelle, Don, and Sam, for sharing your love of the people and places you call home with me.

I will always be grateful to the Rhodes Trust, my referees, and selection panel, for the opportunity to experience, in the words of my friend, Tom Barron – Oxford's *gift of time*. I also want to thank those who supported me, and those who guided me, for making this journey possible before it began.

Thank you, Mum and Dad, for raising me in a home full of love. It is, and always will be, the greatest honour to live by your words and actions. Thank you, Sam and Michael, for making me a proud older brother.

Finally, thank you Amy, for being the most thoughtful companion in this most wonderful of adventures. You inspire me to be a better person, and to live this precious life full of meaning and purpose, and that is perhaps the greatest gift of all.

Declaration

I declare that this thesis is my original research and has not been submitted for a degree at any other university. It includes material from the following peer-reviewed publications:

- **Jones B** and Celemajer DS. Rheumatic heart disease 2025 – current status and future challenges. *Australian Health Review.* 2025.
- **Jones B**, Mitchell A, Haynes E, Howard NJ, Wade V, Pears C, et al. Co-designing the implementation of a rural health systems-strengthening rheumatic heart disease program with remote First Nations Australian communities using Theory of Change. *BMC Health Services Research.* 2025.
- **Jones B**, Turner AW, Marangou J, Yan J, Burgess P, Kaethner A, et al. Recommendations for implementing rheumatic heart disease echocardiographic detection in remote Australia: a narrative review and lesson-drawing from diabetic retinopathy screening. *Australian Journal of General Practice.* 2025.
- **Jones B**, Marangou J, Yan J, Ralph A, Mitchell A, Kaethner A, et al. NEARER SCAN (LENO BESIK) evaluation of a task-sharing echocardiographic active case finding programme for rheumatic heart disease in Australia and Timor-Leste: protocol for a hybrid type II effectiveness-implementation study. *BMJ Open.* 2024.
- **Jones B**, Paterson A, English M, Nagraj S. Improving child health service interventions through a Theory of Change: a scoping review. *Frontiers in Pediatrics.* 2023.
- **Jones B**, Nagraj S, English M. Using theory of change in child health service interventions: a scoping review protocol. *Wellcome Open Research.* 2022.

As first author on these publications, I drafted the manuscripts and integrated feedback from co-authors and journal reviewers.

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List of Abbreviations

ACCHO	Aboriginal Community Controlled Health Organisation
ARF	Acute rheumatic fever
AU$	Australian dollars
BeHEMoTh	Behaviour of interest; Health context; Exclusions; Models or Theories
CMOC	Context–mechanism–outcome configuration
FNCHW	First Nations community health worker
GP	General practitioner
GPO	General practitioner obstetrician
IPT	Initial programme theory
MBS	Medicare Benefits Schedule
NACCHO	National Aboriginal Community Controlled Health Organisation
NEARER SCAN	Non-Expert Acquisition and Remote Expert Review of Screening echocardiography images from Child health and AnteNatal clinics
NPT	Normalisation Process Theory
OFN	Observational field note
RHD	Rheumatic heart disease
SPLASH	Single Parasternal Long Axis view with a Sweep of the Heart
SR	Site report
Strep A	Group A streptococcus
WHF	World Heart Federation

Glossary of Key Terms

Term	Definition
Echocardiographic screening	Echocardiography undertaken to identify previously unrecognised rheumatic heart disease early, in asymptomatic individuals within high-risk populations. This includes both opportunistic screening in routine clinical settings and coordinated, event-based screening.
First Nations	In this thesis, First Nations is used to refer to the first peoples of Australia. First Nations peoples in Australia include hundreds of distinct nations, each with their own histories and cultures. I use the term First Nations because I believe it better reflects the diversity of many individual nations, compared to alternatives such as Aboriginal and/or Torres Strait Islander or Indigenous Australian.
First Nations community health worker	A collective term for an Aboriginal and/or Torres Strait Islander; (a) health practitioner, (b) health worker, or (c) community worker who is employed by a health facility without formal health qualifications.
Generative causation	An understanding of causality as arising not from the programme itself but from the way it modifies contextual conditions to trigger underlying mechanisms that, in turn, generate particular outcomes. This understanding is central to realist approaches.
High-risk population	As defined by a prevalence of more than 2 cases per 1,000 persons for rheumatic heart disease (all ages) or an incidence of more than 30 cases per 100,000 persons aged 5–14 years annually for acute rheumatic fever.
Initial programme theory	An informed but provisional hypothesis about how the programme is expected to cause its intended outcomes that may or may not be realist in nature.
Process evaluation	A type of evaluation of the implementation of a programme that explores what was actually delivered, the extent to which it was delivered as intended, and the overall quality of the implementation.

Term	Definition
Realist evaluation	A theory-based evaluation approach, grounded in a realist philosophy of science, that uses a generative understanding of causation to explain how and why a programme works or doesn't work, for whom, to what extent, in which circumstances.
Realist programme theory	An explanatory account of how and why, a programme works or doesn't work, for whom, to what extent, in which circumstances. It is underpinned by generative casual logic.
Researcher-days	A means of quantifying the observational work done. Defined as the number of days study team members were on-site, with multiple members on the same day counted separately.
Substantive theory	A theory developed within a particular domain (e.g. sociology, psychology, economics) that explains specific phenomena, such as Rogers' diffusion of innovations theory.
Theory-based evaluation	A family of evaluation approaches that make explicit the underlying theory of how and why a programme is intended to work and use this theory to guide data collection and analysis.
Theory of Change	A theory-based evaluation approach which articulates a programme's context, assumptions, intended outcomes with associated indicators, and the rationale for why change is expected to occur at each step.
Programme theory	The underlying theory of how and why a programme is intended to work.

1

Introduction

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1.1 Chapter preface

In this opening chapter, I begin by describing the focus of this thesis – rheumatic heart disease and its early detection through echocardiographic screening. I then provide a brief overview of rheumatic heart disease in Australia, including the current detection landscape and the broader context of First Nations health. Lastly, I outline the thesis rationale, aims, and structure.

This chapter contains content from the following publication:

- **Jones B** and Celemajer DS. Rheumatic heart disease 2025 – current status and future challenges. *Australian Health Review.* 2025.

1.2 Rheumatic heart disease

1.2.1 Definition and pathophysiology

Rheumatic heart disease (RHD) is a condition characterised by chronic damage to the heart valves following an abnormal immune response to childhood group A streptococcal (Strep A) infection, typically of the throat or skin[1]. Household overcrowding increases exposure and transmission of these infections and is the most well described risk factor for RHD[2]. In some individuals, for reasons that remain unclear but likely reflect a complex interplay of host and pathogen factors, untreated infections trigger acute rheumatic fever (ARF). ARF is a multisystem, autoimmune, inflammatory illness affecting the joints, skin, nervous system, and heart[1].

The most serious sequela of ARF is RHD, which can follow a single episode, or recurrent episodes of ARF, leading to progressive scarring of the heart valves, most commonly the mitral or aortic valve. This can result in complications including heart failure, embolic stroke, endocarditis, and atrial fibrillation[3]. Importantly, ARF and RHD are preventable through timely treatment of Strep A infections and, where appropriate, secondary antibiotic prophylaxis to prevent recurrent ARF episodes[1].

1.2.2 Global burden of disease

The most recent Global Burden of Disease study indicates that there are an estimated 55 million prevalent cases of RHD globally, accounting for more than 14 million disability-adjusted life years lost and 375,000 deaths each year[4]. Unlike most cardiovascular diseases, RHD disproportionately affects younger populations and remains the most common acquired cardiovascular disease in children, adolescents, and young adults globally, albeit with marked geographic and socioeconomic heterogeneity[4,5]. RHD burden is concentrated in low- and middle-income countries, particularly across South Asia, sub-Saharan Africa, and Oceania, with high rates also reported in low-resource populations within high-income countries, including First Nations communities in Australia and New Zealand[4,5].

1.2.3 Historical context and current priorities

The socioeconomic and geographic distributions that now define the burden of ARF and RHD were not always the case. In the first half of the twentieth century, ARF and RHD were common globally, affecting populations in both high- and low-income settings. In the United States for example, ARF was reported as the leading cause of childhood mortality in the 1920s and among the most common reasons for paediatric hospital admission[6]. This persisted into the mid-twentieth century, with a 1947 article describing ARF and subsequent RHD as ‘childhood’s greatest enemy’[7]. In the latter half of the century, improved living conditions and widespread access to penicillin contributed to a marked decline in ARF and RHD across high-income settings[8]. By the 1980s, RHD had been largely eliminated in these settings[9], and as incidence fell research interest and policy attention similarly declined[1,8].

Since the 2000s, RHD has re-emerged on the global health agenda, driven by growing recognition of the substantial burden that persists in low-resource settings. This renewed focus has been sharpened by advocacy highlighting the inequities inherent to the disease. The late Professor Bongani Mayosi, a pioneer of RHD research and advocacy, described RHD as “one of the most neglected of the neglected diseases”[10]. The extent of this neglect has been quantified, with a disability neglect index comparing 16 diseases (including RHD, HIV, malaria, and tuberculosis) finding that RHD received the least funding relative to disease burden[11]. International policy commitments have also strengthened, including the World Heart Federation’s roadmap for RHD prevention and control[12], and the World Health Assembly’s 2018 resolution calling for a coordinated global action to address RHD[13].

Contemporary RHD research priorities focus on reducing new disease while improving care for those already affected. Efforts span from improving household infrastructure and living conditions[14], to advancing Strep A vaccine development[15], and strengthening diagnosis and surveillance through point-of-care testing for Strep A infections[16] and biomarker discovery for ARF[17]. Work is also underway to improve delivery of secondary antibiotic prophylaxis through subcutaneous alternatives to the established but suboptimal standard of monthly intramuscular benzathine penicillin injections[18]. This thesis focuses on one priority within this broader agenda – the implementation of echocardiographic screening for earlier detection of RHD.

1.3 Echocardiographic screening for rheumatic heart disease

1.3.1 Early detection and treatment

Early detection of RHD facilitates timely secondary antibiotic prophylaxis, which can prevent disease progression[19,20]. However, early detection remains challenging due to limited access to echocardiography in high-risk settings. Consequently, RHD is still most often recognised only once disease is advanced, when complications and premature morbidity and mortality are more likely[21]. This reflects a missed opportunity to identify RHD while it is mild, when appropriate management can stabilise disease and, in some cases, allow for regression[20].

1.3.2 Evolution of screening

Traditionally, RHD was diagnosed by detecting a murmur on cardiac auscultation, though this was neither sensitive nor specific[22,23]. Following early evidence that echocardiography is more sensitive in detecting subclinical carditis in ARF[24–27], the World Health Organisation included echocardiography among recommended strategies for RHD control as early as 2004, although most of the evidence-base emerged subsequent to this recommendation[28]. In 2007, Marijon et al.[29] published a widely-cited study demonstrating that echocardiography is approximately ten times more sensitive than auscultation for detecting RHD. This finding stimulated an extensive body of work examining the role of echocardiography in identifying RHD, with studies in a range of settings including Australia, Fiji, India, Kenya, Mozambique, New Caledonia, New Zealand, Nicaragua, Nigeria, Pakistan, Sudan, Tonga, Türkiye, and Yemen[30–45]. The diagnostic criteria applied in these studies varied considerably, prompting the World Heart Federation (WHF) to publish the first evidence-based echocardiographic criteria for RHD in 2012[46].

Over the subsequent decade, the WHF 2012 criteria provided a highly specific standard that was adopted internationally. However, because the criteria were developed primarily for research, they were not always straightforward to apply in clinical settings, particularly where specialist expertise and time were limited[47]. In response, efforts to expand access to echocardiographic screening in low-resource, high-burden settings increasingly focused on two complementary approaches: (1) handheld echocardiography using lower-cost portable devices[48–50], and (2) task-shifting and task-sharing models in which briefly trained non-experts apply simplified echocardiographic protocols[51–60].

During this period, the appropriateness of echocardiographic screening (see Box 1.1 for definition) was debated amongst experts, largely because of the uncertain prognostic significance of minor echocardiographic abnormalities, and the unintended consequences of false positives[61]. As the evidence accumulated, including supportive health economic analyses[62–65], increasing consensus emerged that this approach satisfies accepted principles for screening in high-risk populations[1]. This culminated

[1]As defined by a prevalence of more than 2 cases per 1,000 persons for RHD (all ages) or an incidence of more than 30 cases per 100,000 persons aged 5–14 years annually for ARF[66].

in the updated 2023 WHF guidelines for the echocardiographic diagnosis of RHD, which introduced standardised screening criteria and acknowledged the role of handheld echocardiography and non-expert scanning in expanding access to detection[66].

Box 1.1: Screening definition

In this thesis, I use *screening* to describe echocardiography undertaken to identify previously unrecognised RHD early, in asymptomatic individuals within high-risk populations. This includes both event-based screening and opportunistic screening for RHD in routine clinical settings. This differs from the 2023 WHF guidelines, which use *active case finding* as the encompassing term for these approaches. I have opted to use *screening* because it is widely understood across clinical, research, and policy audiences, and is consistent with the terminology used by the National Aboriginal Community Controlled Health Organisation, who are piloting a health system-led echocardiographic screening programme for RHD in Australia (detailed in Section 1.4.3).

1.3.3 Implementing screening

Through the global efforts described above, echocardiographic screening can now be considered an evidence-based intervention with the potential to improve early detection of RHD in high-risk populations[66]. However, to date, only a small number of jurisdictions have delivered health system-led echocardiographic screening programmes, including New Caledonia[35], Tonga[67], and Samoa[68]. These have largely taken the form of periodic school-based screening campaigns with visiting experts, rather than integration into routine service delivery. The research priority is now understanding how screening can be integrated, and implemented reliably, safely, and equitably in real-world settings.

The 2023 WHF guidelines explicitly highlight that implementation research is required to determine the sustainability of different models of echocardiographic screening[66]. Similarly, Rey and Santos[69], in their 2024 *Lancet Global Health* commentary, emphasise that key uncertainties in the field are now related to integration of echocardiographic screening within health systems, the training and ongoing support required for health workers, and longer term cost-effectiveness. Without informed implementation, echocardiographic screening risks being consigned to the 'innovation graveyard', joining many promising, evidence-based interventions that are not integrated into health systems and ultimately fail to reach those most likely to benefit[70].

1.4 Rheumatic heart disease in Australia

1.4.1 National burden of disease

Despite being eliminated from most of the Australian population, 11,794 people were recorded as living with RHD or with a history of ARF on Australian state and territory disease registers at the end of 2024[71]. First Nations Australians overwhelmingly and disproportionately bear this burden. Linked-data population estimates indicate that, although First Nations Australians represent 3.8% of the total population, they accounted for 89% of ARF and 71% of RHD cases, and were at least 60 times more likely than non-First Nations Australians to be affected by either condition[72]. In age standardised estimates, RHD prevalence was highest among First Nations peoples in the Northern Territory (3,545 per 100,000) and Western Australia (1,012 per 100,000)[72]. In one remote community in the Northern Territory, 8% of school-aged children were found to have RHD, representing the highest documented prevalence of RHD globally[73].

1.4.2 First Nations health and wellbeing context

For many First Nations Australians, health is understood as a holistic concept that extends beyond the absence of disease and includes physical, social, emotional, cultural, and spiritual wellbeing at both an individual *and* community-level. In addition to the social and economic determinants that shape health for all people, key determinants of First Nations health and wellbeing include connection to and caring for Country, family and kinship, self determination, and cultural continuity and expression. The ongoing impacts of colonisation, including intergenerational trauma and cultural dislocation, have disrupted these determinants and contribute to the stark health inequities that persist for First Nations Australians today[74].

One widely-used proxy for population-level physical health is life expectancy at birth. In Australia, differences in life expectancy between First Nations and non-First Nations Australians are frequently discussed and often politicised. Recent estimates indicate a gap of 8.8 years for males and 8.1 years for females, widening to 12.4 years for both males and females in remote areas[75].

At the same time, there is substantial work led by First Nations community leaders, and supported by researchers, healthcare workers, and policy advocates, to address conditions that disproportionately affect First Nations peoples. This is true for RHD, where community-led programmes and partnerships have strengthened prevention, care, and advocacy[76]. One persistent challenge, however, consistent with the global experience, is achieving earlier detection of RHD.

1.4.3 Current detection landscape

Current approaches to detecting RHD in Australia largely depend on clinical presentation, with diagnosis only made once symptom severity prompts care-seeking. In remote communities, people typically first present to a local clinic with symptomatic ARF or, in more severe cases, with signs of RHD complications, and are then transferred to a tertiary hospital where the diagnosis of RHD can be confirmed by echocardiography. In this model, opportunities for early detection, before symptom onset when RHD is most amenable to management, are frequently missed.

The consequences of late detection for remote communities in Australia are substantial. Cannon et al.[64] modelled RHD severity progression and outcomes among First Nations people diagnosed aged 5–24 years in the Northern Territory. At diagnosis, 16% already had severe RHD, and outcomes were poor, with 42% undergoing valve surgery within 12 months and around 60% progressing to surgery within four years. In another linked-data analysis, the composite outcome of cardiovascular complication and/or death was experienced by 23% of people diagnosed with previously uncomplicated RHD aged less than 35 years within 8 years[77]. As surgery is often necessary at a young age, repeat procedures are common and mechanical valve replacement with lifelong anticoagulation is frequently required, which is difficult to manage in remote communities due to barriers to regular anticoagulation monitoring[64,78]. These trajectories have implications beyond physical health, as specialist assessment and surgery often require travel to tertiary centres, with time away from community and disruption to schooling, family, and cultural responsibilities.

Echocardiographic screening within communities offers a potential solution to early detection in these settings. The *Deadly Heart Trek*, an expert-led mass-screening programme that combines screening with RHD education and skin checks for Strep A infections has been conducted in several communities over the past five years[79]. It is delivered in partnership with the local communities it visits, and operates as a supplementary service delivery initiative supported philanthropically through The Snow Foundation. However, its reach is necessarily limited as it can only screen a cross-section of the population, and only in the communities it visits.

Recognising these limitations and the scale of the challenge, the National Aboriginal Community Controlled Health Organisation (NACCHO) is currently piloting a health system-led echocardiographic screening programme, *Echo in ACCHOs*, to improve early detection of RHD. NACCHO is the national peak body representing 148 Aboriginal Community Controlled Health Organisations (ACCHOs), which are primary healthcare services governed by local or regional First Nations communities that aim to provide culturally informed care for First Nations people[80]. In 2022, NACCHO announced a major partnership and funding agreement with the Australian Government and BHP, a multinational mining and metals corporation, to support ARF and RHD prevention and care nationally, including a AU$1.5 million investment in echocardiographic screening for RHD[81]. This emerging policy context provides the rationale for the applied focus of this thesis.

1.5 Thesis overview

1.5.1 Thesis aim and objectives

The aim of this thesis is to improve understanding of how echocardiographic screening for RHD can be implemented in remote First Nations communities in Australia.

The specific objectives of this thesis are to:

1. Identify implementation lessons from a comparable screening programme.
2. Review how Theory of Change has been applied to guide the design and evaluation of child health service programmes.
3. Co-design the implementation of an echocardiographic screening programme for RHD, and describe how and why it is expected to improve health outcomes.
4. Assess the implementation of the screening programme using implementation outcomes (fidelity, adoption, penetration, sustainability, and costs).
5. Explain how, why, for whom, to what extent, and in what circumstances echocardiographic screening for RHD can be embedded into routine work for First Nations community health workers.

1.5.2 Thesis structure

Following this introduction, the thesis includes six further chapters: a methods overview, four original research chapters, and a discussion and conclusion. This structure and its relationship to each objective are summarised in Figure 1.1.

Figure 1.1: Relationship between thesis chapters and objectives.

2

Methods overview

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2.1 Chapter preface

In this chapter I introduce the thesis context, including the NEARER SCAN study, and define the scope of the thesis within it. I then outline the thesis orientation, the discipline of implementation science in which the work is situated, the pragmatist and realist paradigms that guide it, and the theory-based evaluation methodology I adopted. Finally, I provide an overview of the data sources and data collection methods, ethical considerations, and reflexivity.

This chapter contains content from the following publication:

- **Jones B**, Marangou J, Yan J, Ralph A, Mitchell A, Kaethner A, et al. NEARER SCAN (LENO BESIK) evaluation of a task-sharing echocardiographic active case finding programme for rheumatic heart disease in Australia and Timor-Leste: protocol for a hybrid type II effectiveness-implementation study. *BMJ Open.* 2024.

2.2 Thesis context

2.2.1 The NEARER SCAN study

This thesis is largely situated within a study called 'Non-Expert Acquisition and Remote Expert Review of Screening echocardiography images from Child health and AnteNatal clinics' (NEARER SCAN). The NEARER SCAN study was a hybrid effectiveness–implementation trial, conducted between August 2022 and December 2025, that evaluated an echocardiographic screening programme for RHD in ten high-risk communities across Australia and Timor-Leste. It was supported by an Australian government Medical Research Future Fund grant and coordinated through the Menzies School of Health Research in Darwin.

Origins of NEARER SCAN

The screening programme was established in response to remote First Nations community leaders' requests for local training in RHD detection to enable earlier diagnosis without requiring specialist visits or hospitalisation at a tertiary centre. In collaboration with these communities, a team of clinicians, sonographers, and researchers designed a course to teach local health workers to conduct simplified echocardiography using a handheld device.

Staff were trained to perform the Single Parasternal Long Axis view with a Sweep of the Heart (SPLASH) abbreviated echocardiographic protocol[82]. The protocol involves acquiring a parasternal long-axis view and adjusting the probe angle to obtain two-dimensional and colour Doppler images of the mitral and aortic valves, enabling detection of pathological regurgitation and key morphological features of RHD. This requires approximately 10 minutes for a non-expert, and can be performed without the removal of clothing, by positioning the probe on the chest through a lowered shirt collar.

A series of diagnostic accuracy studies were undertaken to establish an evidence base for training non-expert local health workers to perform SPLASH scans[58,60]. In these studies, general practitioners (GPs), nurses, and community health workers from Australia and Timor-Leste performed handheld echocardiography after SPLASH training. In the RECARDINA study, which assessed a task-sharing model, local health workers acquired images that were reviewed remotely by off-site experts. The experts' interpretations of these scans served as the index test, compared against expert-performed full diagnostic echocardiograms for abnormal SPLASH scans and expert-performed SPLASH scans for normal scans[60]. Using this task-sharing model, the programme achieved a sensitivity of 76.7% (95% CI: 68.5–83.7%) and specificity of 94.9% (95% CI: 94.0–95.6%) for the criteria carried forward into NEARER SCAN[60]. These studies also further highlighted the extent of undetected RHD[73]. Building on this foundation, the NEARER SCAN study was designed to evaluate implementation beyond the controlled conditions of diagnostic accuracy studies, in settings more reflective of real-world practice (albeit still within a research context).

NEARER SCAN screening programme

The screening programme in NEARER SCAN adopted the the task-sharing model described above. Staff in high-risk communities were trained to operate a handheld echocardiographic probe connected to a tablet with the SPLASH abbreviated protocol to obtain cardiac images. The target population consisted of children and young people aged 5–20 years and pregnant women, the groups at highest risk of RHD. The images were uploaded to a cloud-based image platform and interpreted off-site by cardiologists (Figure 2.1).

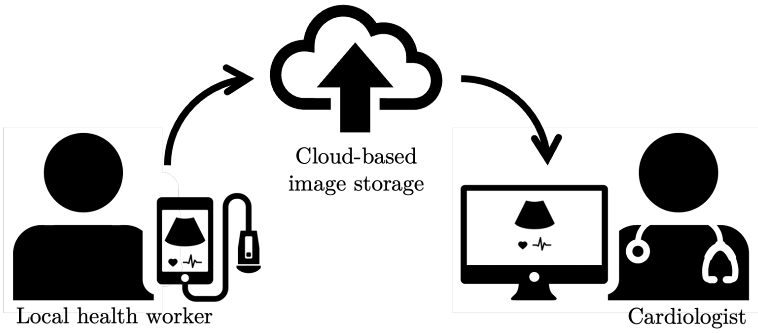

Figure 2.1: Process of echocardiographic image acquisition and review.

Trained local healthcare staff included First Nations community health workers (FNCHWs)[1], nurses, and GPs. For FNCHWs in particular, performing handheld echocardiography was a substantial departure from their usual responsibilities[84]. The implications of this shift are explored further in Chapter 6. Training consisted of four days of in-person instruction by cardiac sonographers: two days of theory and two days of practical training. Trained staff were then required to complete 100 training scans (which could be conducted on anyone, including the same person multiple times) recorded in a logbook and pass a practical assessment to graduate as a SPLASH scanner.

Images were uploaded from the tablets to a secure cloud-based medical image storage platform, to be reviewed remotely by cardiologists within 72 hours. Scans were classified as normal, abnormal, or uninterpretable. Participants with abnormal scans were referred for full diagnostic echocardiography to be conducted within three months at the closest referral hospital; those with uninterpretable scans were scheduled for repeat screening; and those with normal scans were scheduled for repeat screening after 12 months. A flowchart of the various pathways of the screening programme is provided in Figure 2.2.

[1] I use First Nations community health workers as a collective term for Aboriginal and/or Torres Strait Islander (a) health practitioners, (b) health workers, and (c) community workers employed by a health facility without formal health qualifications[83]. This reflects the analytic focus of the evaluation on shared experiences of the programme rather than distinctions between these cadres of the Australian health workforce.

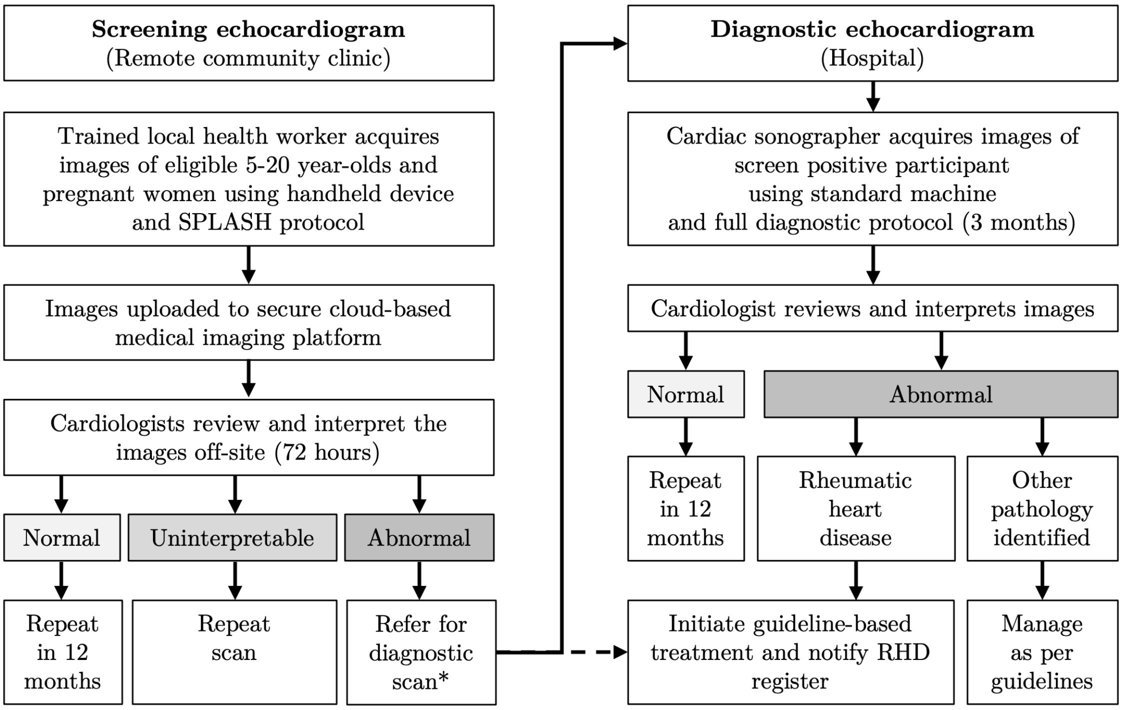

Figure 2.2: Screening and diagnostic echocardiography pathways. *Participants with markedly abnormal screening scans were occasionally initiated on treatment before diagnostic echocardiography. Adapted from Jones et al.[85]. SPLASH = single parasternal long axis view with a sweep of the heart.

Whilst the key elements of the screening described above were consistent across the sites, the exact configuration of the programme differed slightly, reflecting local staffing and priorities (detailed in Chapter 4). Prior to training, an implementation design process of approximately six months was undertaken at each participating facility. During this period, decisions were made with local stakeholders about which staff should be trained (e.g. professional background and number of staff), when screening should occur (e.g. opportunistically, during clinics, or at community events), and which implementation strategies would best support the programme. The stakeholders involved and the data sources for this work are described in Section 2.4, while the process and outcomes are presented in Chapter 4.

NEARER SCAN study design

The NEARER SCAN study was designed as a type II effectiveness–implementation hybrid trial[86]. In this study design there is simultaneous evaluation of a clinical intervention (the echocardiographic screening programme) and the implementation approach.

Clinical effectiveness was evaluated by examining the impact of the programme on clinical outcome measures. The primary outcome was the change in the proportion of the target population prescribed secondary prophylaxis for RHD at the end of the study compared with baseline. The sample size was set at 1,500 participants in total across 10 sites in Australia and Timor-Leste, reflecting the anticipated scale of the programme. Secondary outcomes included measures of patient progression through stages of care, from screening scan to secondary prophylaxis adherence.

2.2.2 Scope of thesis within NEARER SCAN

The scope of this thesis within the NEARER SCAN study was to evaluate the implementation of the programme within the Australian sites (Figure 2.3). The analysis of clinical effectiveness has not yet been conducted. Once complete it will be reported separately to the implementation evaluation work conducted in this thesis.

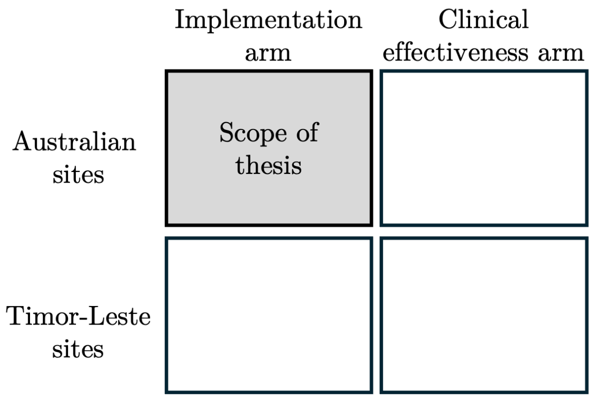

Figure 2.3: Scope of this thesis within the NEARER SCAN study.

Thesis study sites and facilities

This research was conducted in five remote First Nations communities: Karratha-Roebourne in the West Pilbara region of Western Australia, and Milikapiti, Maningrida, Galiwin'ku, and Yirrkala in the Top End of the Northern Territory (Figure 2.4). Sites were purposively selected to reflect the facilities expected to take part in future screening efforts[81]. To protect participant identity, particularly given the small staff sizes at each site facility, sites are referred to using pseudonyms throughout this thesis (Site 1–5), listed in random order.

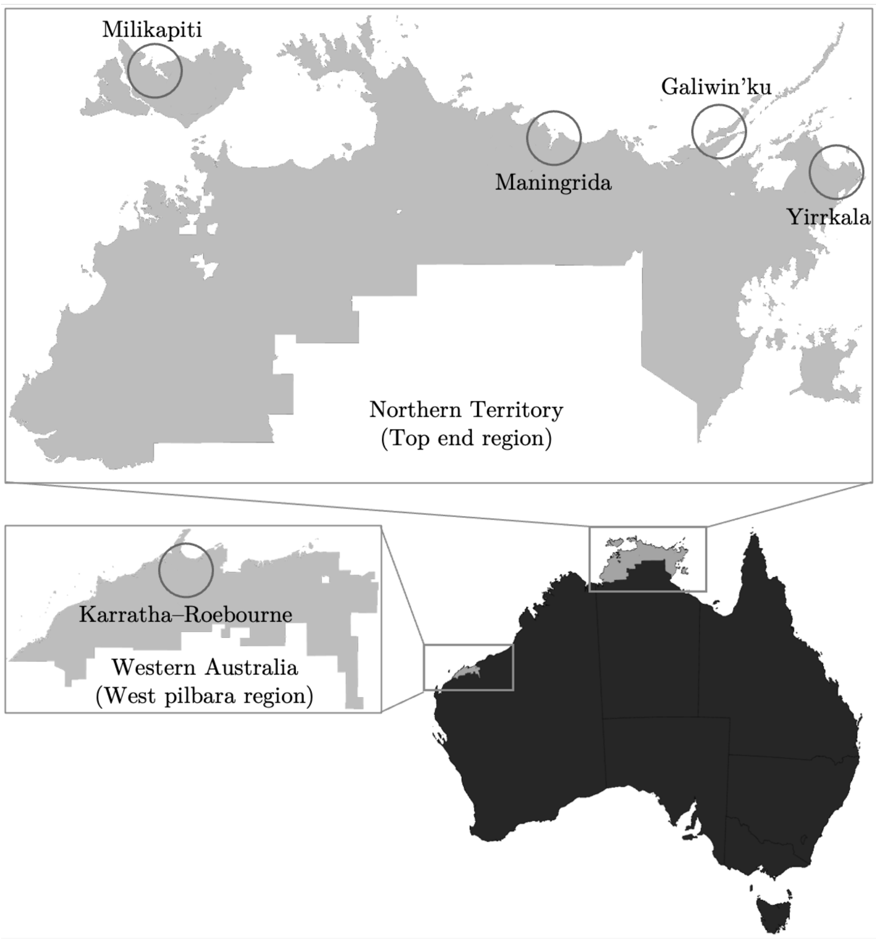

Figure 2.4: Map of Australia showing the locations of the five study sites.

Participating facilities were either ACCHOs or state/territory government-run clinics (Table 2.1). Across all participating facilities, the scope of practice was largely primary care, with some health promotion, after-hours services, and emergency care and stabilisation prior to retrieval, usually by air, to referral hospitals. These facilities typically operate with relatively few staff. One study of 53 Northern Territory government-funded clinics reported that, at any time point, clinics had a median of 2.0 nurses, 0.4 agency-employed nurses, 0.6 Aboriginal health practitioners, and 2.2 non-clinical employees[87]. These teams are sometimes supported by general practitioners and/or visiting fly-in fly-out specialists.

Karratha–Roebourne was managed as a single study site but involved scanners working across the Karratha health campus and Roebourne hospital. Karratha is a regional hub shaped by the natural resources industry, with a comparatively larger non–First Nations population and more extensive health infrastructure than the other study sites. Roebourne is a First Nations community located approximately 30 minutes drive from Karratha and is more comparable to the Northern Territory sites.

Table 2.1: Study site details

Characteristic	Karratha / Roebourne	Milikapiti	Maningrida	Galiwin'ku	Yirrkala
Population	22,199 / 975	414	2,518	2,199	657
Proportion of residents who are First Nations (%)	12 / 74	94	91	92	80
Facility governance	Western Australia Government	Northern Territory Government	ACCHO	ACCHO	ACCHO
Travel options to tertiary referral hospital	2 hr flight (20 hr drive)	30 min flight (no road)	1 hr flight (7 hr drive (dry season))	2 hr flight (no road)	2 hr flight (12 hr drive (dry season))

Demographic data were sourced from the most recent census as reported by the Australian Bureau of Statistics (2021)[88]. Travel times are approximate. Road access to some Northern Territory sites is during the dry season only due to flooding in the wet season. Census figures provide a general impression but should be interpreted with caution given the known under-reporting in these settings[89]. ACCHO = Aboriginal community controlled health organisation.

2.3 Orientation to thesis

2.3.1 Implementation science

This thesis is positioned within the discipline of implementation science. Implementation science is defined as 'the study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice'[90]. A frequently cited estimate suggests that it takes an average of 17 years for research evidence to reach routine practice, with only around 14% of scientific discoveries ever becoming widely adopted[91,92]. While these figures are contested and perhaps simplify complex translational processes, they nevertheless capture the persistent sense of inefficiency within research that implementation science seeks to address.

Implementation science as a distinct discipline has origins in earlier work on diffusion of innovations[93], policy implementation[94], and evidence-based practice in the 1990s, though some trace its origins further back to health services research and delivery science. It gained more formal recognition as a discipline with the launch of the journal, *Implementation Science*, in 2006[90] and has since expanded substantially[95].

2.3.2 Pragmatic and realist paradigms

In this thesis, both pragmatism and realism are adopted as philosophical paradigms to guide the research.

Pragmatism

Pragmatism positions reality as continually debated and reinterpreted. Epistemologically, it holds that truth is judged by its practical consequences[96]. Pragmatism links knowledge to action by valuing research for its usefulness, recognises the fallibility and evolving nature of science, and embraces methodological pluralism as a valid means to improve understanding[97].

Realism

Realism informs this thesis in line with the account set out by Pawson and Tilley[98]. It acknowledges that both the material world and a social world are 'real' and cause real changes that we can *partially* understand. This draws on Bhaskar's critical realist ontology, which distinguishes between three domains[99]. The *empirical*, which refers to the experiences we can access through our senses. The *actual*, which is the wider domain of events that occur independently of our perceptions (*mind-independent reality*). Finally, the *real*, which is the domain of underlying mechanisms and structures that generate events, even if they are not directly accessible. The epistemological foundations draw on Popper's view of knowledge as provisional[100], illustrated by his metaphor of building on a swamp where progress relies on the continual testing and rejection of ideas, without secure foundations[101].

Using both paradigms

Pragmatism and realism are used in this thesis in a complementary way. Both share a fallibilist orientation, a commitment to methodological pluralism, and a focus on generating useful knowledge. Rather than attempting to merge the two, this thesis makes purposeful use of each paradigm where it best fits the research question. Pragmatism guides most of the thesis, directing inquiry toward practical consequences, while realism provides the philosophical foundation for the explanatory approach used in Chapter 6.

Using more than one distinct paradigm remains contested, with some scholars arguing that differing underlying ontological and epistemological positions are too divergent to be coherently reconciled within a single piece of work[102]. Others contend that certain combinations can be productive, and pragmatism and realism are two paradigms frequently considered together[103,104,105,106]. This is perhaps unsurprising, as leading realist thinkers have at times drawn, implicitly or explicitly, on the work of key pragmatists[104]. Some have even sought to combine these into a new paradigm of pragmatist–critical realism[106]. This thesis does not attempt to resolve these philosophical debates.

2.3.3 Theory-based evaluation

The main methodology utilised in this thesis is that of theory-based evaluation. Theory-based evaluation refers to a family of evaluation approaches that make explicit the *programme theory*, the underlying hypothesis of how and why a programme is intended to work, and use this theory to guide data collection and analysis[107,108]. These different approaches vary in their process and can overlap in practice. In this thesis, two of these approaches are used, Theory of Change and realist evaluation.

I adopted theory-based evaluation approaches for two main reasons. First, the echocardiographic screening programme was a complex intervention, for which a theory-based evaluation is recommended in the UK Medical Research Council's guidance on complex interventions[109]. Second, within the field of First Nations health, evaluations have at times been criticised for a limited capacity to produce learning that informs better practice across programmes[110]. Accordingly, the Australian Productivity Commission's *Indigenous Evaluation Strategy*[111] recommends theory-based evaluation as a structured approach to generate transferable insights.

Origins of theory-based evaluation

Theory-based evaluation emerged in the 1980s in response to concerns that evaluations were becoming increasingly superficial, 'box-ticking' exercises. The political and economic climate of Thatcherism and Reaganomics meant public institutions in much of the Western world were mandated to evaluate their programmes[112,113]. In practice, this often produced poor evaluations, as the principle of learning was displaced by a drive to demonstrate success to secure further funding. This environment did benefit some: evaluators had plenty of work, politicians could find evaluations to suit their position, and society was reassured that publicly funded programmes were being 'evaluated'.

At the same time, this environment exposed the *Martinson problem*[98,114], where evaluations produced oversimplified conclusions (e.g. 'sometimes it works and sometimes it doesn't'), typically coupled with a call for more research. Such findings offered little value from a learning standpoint. In response, evaluation scholars advanced theory-based evaluation, building on earlier work on programme theory[112,115–118]. Their aim was to strengthen evaluation practice by offering an approach that supported more meaningful learning across programmes.

Theory of Change

A Theory of Change articulates a programme's context, assumptions, intended outcomes with associated indicators, and the rationale for why change is expected to occur at each step[119–121]. These components combine to create a representation of how and why a programme is intended to bring about change (i.e. *a programme theory*), which is usually represented as a map diagram. A Theory of Change can be applied in both design and evaluation, either prospectively or retrospectively[121]. In this thesis, I intentionally capitalise Theory of Change to signal that I mean its use as a formal theory-based evaluation approach, with its origins from the Aspen Institute in community development evaluation[119–121] and more recently through the work of the Center for Theory of Change[122]. This is to distinguish it from the everyday use of 'theory of change' to simply mean an idea of how change could be brought about.

I understand Theory of Change as a distinct approach within the broader family of theory-based evaluation approaches, closely related to, but distinct from, logic models. I agree with De Silva et al.[123], who argue that, strictly speaking, logic models are simpler, more linear, and more rigid representations than true Theories of Change. Unlike Theories of Change, logic models typically do not articulate underlying assumptions, specify indicators, explain the underlying rationale of outcome sequences, or allow for multiple causal pathways. In this way, they might be considered a 'partial' Theory of Change.

I initially considered using a Theory of Change approach for both the design and evaluation of the echocardiographic screening programme, given its emphasis on stakeholder involvement[123], a feature widely recognised as critical in First Nations health research. To assess its suitability, I conducted a scoping review of how it has been applied for these purposes across similar programmes (Chapter 3). In brief, I found that while valuable for guiding the implementation design (Chapter 4) and assessing fidelity as part of the process evaluation (Chapter 5), a Theory of Change alone would not offer the explanatory depth required to address the thesis research questions. The approach was therefore complemented with a realist evaluation. A discussion on combining these two theory-based evaluation approaches is presented in Chapter 7.

Realist evaluation

Realist evaluation is another theory-based evaluation approach. It is grounded in a realist philosophy of science and addresses the questions of 'what works, for whom, under what circumstances, and how[98,124]?' These questions arise from an understanding that programmes do not work for everyone, nor do they work all of the time, but rather, that there will inevitably be variation in the conditions under which programmes work.

Realist evaluation originates from Pawson and Tilley's seminal work, 'Realistic Evaluation'[98]. Central to this work is the concept of *generative causation*, which is an understanding of causality as arising not from the programme itself but from the way it modifies contextual conditions to trigger underlying mechanisms that, in turn, generate particular outcomes. In this understanding, *mechanisms* are hidden, context-sensitive, causal forces.

The key heuristic in realist evaluation is the *context–mechanism–outcome configuration (CMOC)*, which provides a structured way to represent hypotheses of generative causation[98,124]. The aim of a realist evaluation is to refine a *realist programme theory*, which is an explanatory account of how and why, a programme works or doesn't work, for whom, to what extent, in which circumstances. It is underpinned by generative casual logic. Realist programme theories are formulated at the level of a middle-range theory, which, as Merton[125] described, is sufficiently abstract to apply across comparable cases but 'close enough to the observed data to be incorporated in propositions that permit empirical testing'.

2.4 Data sources and collection

Having outlined the disciplinary, paradigmatic, and methodological orientation of the thesis, this section describes the data sources and data collection methods used to support the empirical results presented in Chapters 3–6, and concludes with ethical and reflexive considerations. Figure 2.5 provides an overview of the data used across these chapters.

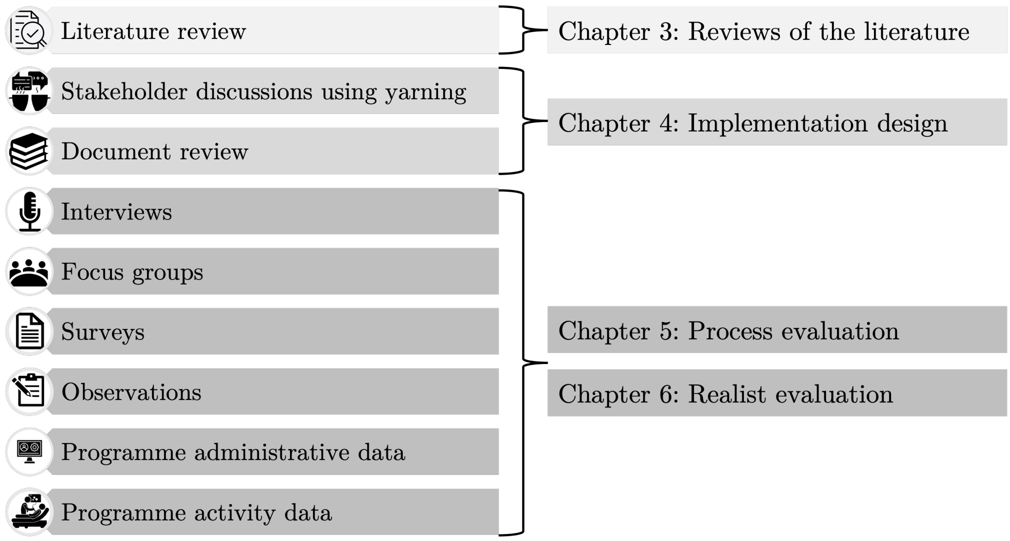

Figure 2.5: Overview of data sources and how each was used in the analyses presented in the results Chapters 3–6 of this thesis.

2.4.1 Reviews of the literature

The first results chapter of this thesis, Chapter 3, includes two literature reviews undertaken to guide the subsequent design and evaluation of the echocardiographic screening programme. The first, a narrative review (Part A) on the implementation of a comparable screening programme in Australia, was conducted to draw on the implementation lessons observed in similar settings. The second, a scoping review (Part B), mapped how a Theory of Change approach had been used in similar programmes and, in doing so, allowed for consideration of how it might help in evaluating the echocardiographic screening programme. Full details of the methods and findings of both reviews are presented in Chapter 3.

2.4.2 Implementation design

The second results chapter, Chapter 4, presents a qualitative work package guided by a Theory of Change approach. The Theory of Change originated from a preliminary idea about how and why the programme would work. This idea was then adapted for each site through the implementation design process in collaboration with local stakeholders. Stakeholders included facility managers, staff considered for training (FNCHWs, nurses, and GPs), community leaders, people and families with lived experience of RHD, and representatives from other community services such as schools, language centres, and local government. These groups were included to capture a broad range of perspectives.

Between February and June 2023, members of the NEARER SCAN study team, including myself, visited each site to conduct discussions and record field notes. During these visits, implementation design discussions were held with local stakeholders. These discussions took the form of *yarning*, a conversational process of telling and sharing stories and information that has been formalised as a qualitative data collection method[126–128]. I chose yarning for its grounding in First Nations worldviews and alignment with local ways of conversing. These yarning discussions were a mix of informal and formal, group and individual conversations. The content of these discussions was guided by the Theory of Change components, using a discussion guide I developed for this purpose (Appendix A.1).

These visits amounted to 40 researcher-days (defined as the number of days study team members were on-site, with multiple members on the same day counted separately) over five months, which generated 60 pages of observational field notes.

These discussions were not recorded, in recognition of the importance of prioritising trust and relationship building during the initial stages of engagement. This approach was endorsed by the NEARER SCAN Indigenous Advisory Group[2]. Instead, data were documented in the form of observational field notes, which captured the content of discussions as well as contextual insights. Additional data sources included documents relating to RHD guidelines and policies.

[2]The Indigenous Advisory Group was a group of First Nations peoples working on the NEARER SCAN study or work related to RHD. The group met quarterly and guided the NEARER SCAN study in accordance with culturally safe research principles. I was a member of this group.

2.4.3 Process evaluation and realist evaluation

The final two results chapters, Chapters 5 and 6, detail the evaluation of the programme. Chapter 5, the process evaluation, outlines an assessment of the implementation outcomes, including fidelity, adoption, penetration, sustainability, and cost, to describe what was implemented across sites and how successful this was. Chapter 6, the realist evaluation, extends this analysis by explaining what worked, where, for whom, why, and under what circumstances. Together, these chapters provide both an empirical account of the programme's implementation and an explanatory analysis of the factors that shaped it. Findings from the process evaluation, particularly regarding the extent and variability of implementation across sites, informed the framing and interpretation of the subsequent realist evaluation. The temporal sequence of data collection, analysis, and write-up for the evaluation is shown in Figure 2.6.

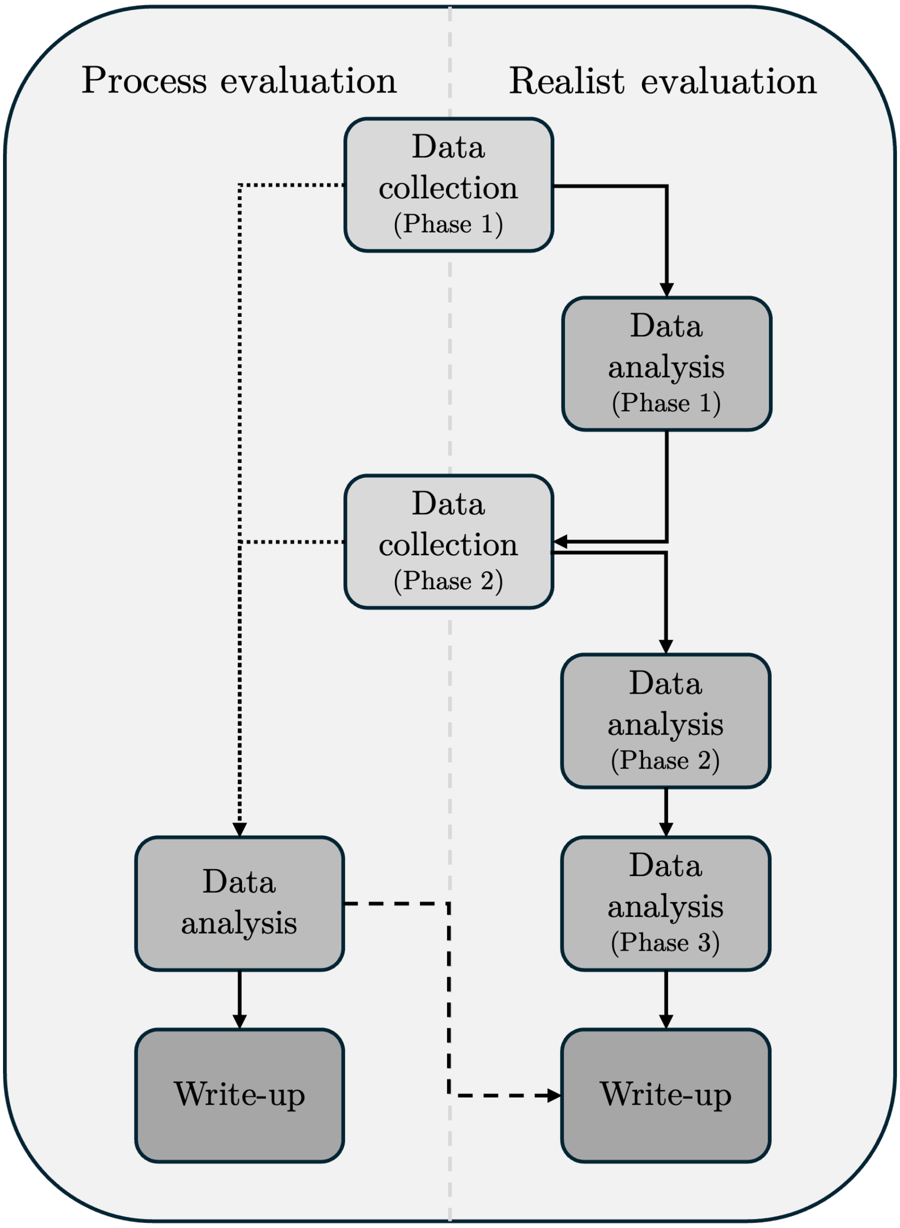

Figure 2.6: Sequence and interrelationship of the process and realist evaluations. The iterative phases of data collection and analysis for the realist evaluation were conducted first, followed by the data analysis of the process evaluation which informed the write-up of the realist evaluation. Arrows indicate the temporal flow of data collection, analysis, and write-up across the two evaluations, and dotted arrows show that the process evaluation analysis occurred after the realist evaluation. The dashed arrow shows where insights from the process evaluation informed later stages of the realist evaluation.

Both evaluations drew on the same data described below but for different purposes. I used the data to perform a descriptive analysis of implementation success in Chapter 5 and then to perform a realist analysis in Chapter 6. The realist evaluation provided the overarching structure for data collection, so the data and methods described in this section are framed primarily around that work package.

Qualitative and quantitative data were collected from multiple sources across multiple phases. I adopted this approach to enable triangulation of findings. Data were collected with the purpose of drawing inferences on programme context, mechanisms, outcomes, and the relationships between CMOCs to form a more refined programme theory. The nature of the data collection varied throughout the theory refining process, as detailed in the relevant data type sections. In general, the first phase of data collection was more exploratory, whereas later phases were more focused in order to collect sufficient data on emerging aspects of the programme theory to help refute or refine the knowledge claims that were developing.

This evaluation included the use of both primary and secondary data sources. Primary data included semi-structured realist interviews, realist focus groups, Normalization MeAsure Development (NoMAD) surveys, and observational data. Secondary data were drawn from programme activity and administrative data.

For clarity of reporting, the realist evaluation was organised into iterative phases aligned with cycles of data collection and analysis: Phase 1 (May 2023–October 2024), focused on primary data collection and initial qualitative analysis; Phase 2 (November 2024–June 2025), involving further primary data collection and qualitative analysis; and Phase 3 (July 2025), focused on secondary data collection and quantitative analysis.

2.4.3.1 Primary data

Primary data were collected through interviews, focus groups, surveys, and observational field notes. The inclusion and exclusion criteria for participants in the interviews, focus groups, and surveys are outlined in Table 2.2.

Table 2.2: Evaluation participants inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Staff member at a participating facility (e.g. managers, staff conducting the scanning, other staff); or cardiologist reviewing images through central cloud-based image storage system. Available to participate without adversely affecting service delivery.	Not willing or able to provide informed consent.

Sampling

Purposive sampling was used for the interviews, focus groups, and surveys. Participants were purposively selected initially to maximise variation across key programme characteristics such as the different sites and cadre of scanners. Later in the evaluation a purposive theoretical sampling approach was used where participants were chosen based on how well they were placed to provide insights into aspects of the emerging programme theory. Both purposive approaches served to capture the diversity of experience within the programme and refine the programme theory[129].

The sample size was guided by the concept of information power[130]. Information power suggests that the more relevant information participants hold for the study aim, the fewer participants are needed. I found this approach well suited to a realist approach, as it prioritises the generation of new insights over representativeness, and complements the iterative nature of realist enquiry.

Across Phase 1 and 2 of the evaluation, the primary data collected included 36 interviews, 7 focus groups, 39 NoMAD surveys, and 200 researcher-days of observation over 24 months (median 5 visits per site), which generated 224 pages of field notes (Table 2.3).

Table 2.3: Overview of primary data collected for evaluation

Method	Phase I	Phase II	Total
Interviews	18	18	36
Focus groups	2	5	7
Surveys	23	16	39
Observations (researcher-days / number of pages of field notes)	125 / 130	75 / 94	200 / 224

Interviews

Semi-structured realist interviews are theory-driven, drawing on the teacher–learner cycle in which the interviewer shares an understanding of an element of programme theory and the participant responds with feedback that constitutes the interview data[98]. I adopted this approach because it is specifically designed to elicit, test, and refine realist programme theories[131].

The content of each interview varied according to both the stage of the evaluation and the participant. Interviews were tailored to each participant, recognising that different individuals could contribute insights into different aspects of the emerging programme theory[98]. Tailoring also reflected the evaluation phase, drawing on Manzano's[131] stages of theory gleaning, refining, and consolidating. In the first phase, questions were general and exploratory, aimed at uncovering candidate theories. In the second phase, questions focused on specific CMOCs that I developed based on data from the previous phase, and participants were encouraged to support or challenge these by providing examples or counterexamples.

A total of 36 interviews were conducted across all five study sites: 18 in Phase 1 (December 2023) (Table 2.4) and 18 in Phase 2 (May–June 2025) (Table 2.5). Depending on participant preference, interviews were conducted in person, by phone, or via video call. They lasted approximately 15–45 minutes, were audio-recorded with consent, and transcribed verbatim.

I conducted the majority of interviews, with an additional five Phase 2 interviews conducted by Alice Mitchell, a qualitative researcher in the evaluation team. Alice, as an Australian-based researcher, conducted interviews when it was not feasible for me to attend in person, as we considered face-to-face interviews likely to yield richer data than an online format for some participants. I received training in realist interviewing in November 2023 at the *Realist Methodology Training Conference* run by the Centre for Advancement in Realist Evaluation and Synthesis, and I also drew on advice from fellow DPhil students conducting realist research within the Health Systems Collaborative research team in Oxford. I guided Alice in the realist-specific aspects of interviewing. For each cadre and phase, I developed an interview guide, which we piloted through practice interviews to refine our technique (an example guide is provided in Appendix A.2).

Table 2.4: Phase 1 interview participants

Cadre	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Total**
FNCHW	0*	2	3	1	1	7
Nurse	0*	N/A	2	1	1	4
GP	N/A	N/A	N/A	N/A	1	1
Manager	1	1	2	1	1	6
Total	1	3	7	3	4	18

*Indicate cadres who contributed via focus groups rather than interviews. N/A = not applicable.

Table 2.5: Phase 2 interview participants

Cadre	Site 1	Site 2	Site 3	Site 4	Site 5	Total
FNCHW	2	1	1	3	0	7
Nurse	1	N/A	1	N/A	0	2
GP	N/A	N/A	N/A	1	1	2
Manager	1	1	0	1	0	3
Cardiologists	N/A	N/A	N/A	N/A	N/A	4
Total	4	2	2	5	5	18

Focus groups

Realist focus groups, like realist interviews, are theory-driven and draw on the teacher–learner cycle (or, in the case of groups, a classroom cycle). The group setting introduces distinctive features such as collective reasoning, disagreement, and subgroup analysis[132].

A total of seven focus groups were conducted (Table 2.6). Phase 1 focus groups were held in December 2023 at Site 1 instead of individual interviews, in line with local preference. Phase 2 focus groups took place during the community of practice workshop meeting in April 2025 in Darwin, where scanners from across the sites met to discuss the programme. Depending on participant preference, focus groups were conducted in person or via video call. Each lasted approximately 60 minutes, was audio-recorded with participant consent, and transcribed verbatim.

I facilitated the focus groups in Phase 1. In Phase 2, the focus groups were conducted by other NEARER SCAN study team members, as I was unable to attend the workshop in person. The two realist focus groups were facilitated by Alice Mitchell and my supervisor, Josh Francis, using guides I had developed (Appendix A.3). In addition, a yarning-style focus group approach was used for the First Nations scanner groups. These were facilitated by First Nations research assistant, Raelene Collins, and senior First Nations researcher, Vicki Wade, with the approach selected to reflect their expertise and experience.

Table 2.6: Focus group particpants

Focus group	Phase	Number of participants	Participants
1	1	5	Site 1 scanners
2	1	3	Site 1 managers
3	2	4*	GP scanners
4	2	5	Nurse scanners
5	2	3	First Nations scanners
6	2	3	First Nations scanners
7	2	3	First Nations scanners

*Two additional GP obstetricians were invited to participate in the GP focus group discussion, extending recruitment purposively to capture variation from the regional hospital NEARER SCAN study site that was demonstrating greater success in implementing the programme than the remote sites included in this thesis.

Surveys

The NoMAD survey is a 23-item questionnaire derived from the core constructs of Normalization Process Theory (NPT)[133]. I chose this tool because NPT had emerged as a relevant substantive theory (defined later in this Section) during initial programme theory development (detailed in Part A of Chapter 6). The survey was intended to complement the secondary quantitative data by providing implementation-focused outcome patterns and supporting the interpretation of variation between sites and cadres of scanners. I adapted the survey to reflect the RHD screening programme and the specific implementation environment of First Nations community facilities (Appendix A.4).

A total of 39 surveys were collected across the five study sites: 23 during Phase 1 (December 2023) (Table 2.7) and 16 during Phase 2 (May–June 2025) (Table 2.8). Surveys were self-administered and completed either in person or digitally, before or after interviews and focus groups.

Table 2.7: Phase 1 survey participants

Cadre	Site 1	Site 2	Site 3	Site 4	Site 5	Total
Scanner	5	1	3	2	3	14
Other staff	0	1	2	0	0	3
Manager	3	0	2	0	0	6
Total	8	2	7	2	4	23

Table 2.8: Phase 2 survey participants

Cadre	Site 1	Site 2	Site 3	Site 4	Site 5	Total
Scanner	2	2	2	2	1	9
Other staff	0	0	0	0	0	0
Manager	1	1	0	1	0	3
Cardiologist	N/A	N/A	N/A	N/A	N/A	4
Total	3	3	2	3	1	16

Observations

Observations, recorded as fieldnotes and site visit reports, were used primarily to capture aspects of programme context. A participant-as-observer approach was adopted, as most external NEARER SCAN study team members contributing observations were both known to be researchers and actively involved in programme implementation[134].

In total, 200 researcher-days of observation were conducted across the five study sites over 24 months: 125 during Phase 1 (July 2023–October 2024) and 75 during Phase 2 (November 2024–June 2025), generating 224 pages of fieldnotes recorded both during site visits (median 5 visits per facility, range 4–9) and between visits. Observations were conducted by nine NEARER SCAN study team members, including three sonographers, three principal investigators (two paediatricians and one cardiologist), two evaluators (myself and Alice Mitchell), and the project coordinator. While a general observational guide (Appendix A.1) supported consistency, researchers also documented unstructured reflections that emerged during fieldwork. In addition to fieldnotes, formal site visit reports were completed. Fieldnotes were primarily documented via secure WhatsApp groups that included ten core NEARER SCAN study researchers, with separate group chats created for each of the five sites as well as one general group. This platform facilitated real-time, iterative data collection, enabling researchers to share observations alongside ongoing logistical and implementation-related information.

2.4.3.2 Secondary data

In addition to the primary data, secondary data from the clinical effectiveness arm of the trial and programme records were incorporated. These data were collected in July 2025 with permission from the study investigators and local ethics committees, and were used to inform the process evaluation and the realist evaluation, particularly in understanding outcome patterns.

Programme administrative data

Throughout the evaluation, I worked with Meghan Bailey, the NEARER SCAN project coordinator, to identify information collected through routine programme implementation that could inform the evaluation. These data included site visit dates, scanner cadre, and training progress, accessed via a secure, shared OneDrive. In addition, I drew on data from the cloud-based medical imaging storage platform to determine the time taken to review scans following upload.

Programme activity data

Programme activity data in the form of scan records were used to characterise how successfully the programme was implemented across sites and to provide objective indicators of implementation rather than clinical outcomes.

Scan records were collected and managed using REDCap V.13 electronic data capture tools (Vanderbilt University, USA), hosted at Menzies School of Health Research in Darwin[135,136]. Demographic and clinic data were obtained from the participating sites' primary healthcare systems and the state-based RHD registers by a NEARER SCAN study research assistant. For the evaluation, I used selected fields including record ID, recruitment site, date of acquisition and interpretation, name of staff performing the scan, scan results, and image quality.

For Sites 2–5, scan activity data were extracted from REDCap for individuals aged 5–20 years with scans uploaded between 1 May 2024 and 30 June 2025. This period covered the establishment of the REDCap through to the end of Phase 2. Pregnant women were excluded because, based on available data, it was not possible to distinguish whether a scan was conducted as part of clinical care during pregnancy or as a purely practice, training scan on staff. Focusing on scans of individuals aged 5–20 years therefore ensured consistency in the dataset. The cloud-based image storage platform was also used to assess the implementation outcome of adoption within the process evaluation.

At Site 1, REDCap use was limited, with most scan outcomes communicated directly by a visiting cardiologist rather than systematically entered into the database. To estimate scanning activity, records from the cloud-based image storage platform were used to identify scans of individuals aged 5–20 years during the same time period. As upload practices varied, these figures may not fully reflect the total scanning activity. This limitation is noted here and considered further in interpreting the process evaluation findings in Chapter 5.

Reflective learning

I complemented the collected data with input from three advisory groups that included NEARER SCAN programme implementation team members, First Nations advisors via the Indigenous Advisory Group, and realist researchers in my research team in Oxford, the Health Systems Collaborative. These groups provided feedback on the emerging programme theory but did not contribute primary data, other than the observational field notes of the NEARER SCAN team members.

In addition, I maintained a digital research journal using a note-taking application, Logseq, to document reflections on my positionality and potential biases as they arose. Reflexive journaling is particularly important in realist evaluations, which emphasise the role of the researcher in data interpretation. The journal also served as an audit trail, supporting my ability to be transparent in reporting the evaluation (as discussed in Chapter 6).

Substantive theories

A substantive theory, also known as a formal theory, is a theory developed within a particular domain (e.g. sociology, psychology, economics) that explains specific phenomena, such as Rogers' diffusion of innovations theory[93,137].

Several substantive theories were drawn upon throughout the thesis to complement the empirical data and further explain the findings. An overview of the theories that most influenced the thesis are provided in Table 2.9.

Table 2.9: Substantive theories in thesis

Theory	**Overview**
Normalisation process theory (NPT)[138]	NPT is a sociological theory commonly applied in implementation research that helps to explain how new technologies become routinely embedded within social systems. It focuses on what people do, individually and collectively, to enact innovations within their work, rather than on their attitudes or intentions. NPT comprises four interrelated components: coherence (sense-making work), cognitive participation (relational work), collective action (operational work), and reflexive monitoring (appraisal work), each shaped by the broader organisational and social environment.

Table 2.9 – continued from previous page

Theory	Overview
Street-level bureaucracy[139]	Street-level bureaucracy explains how frontline public service workers, such as teachers, police officers, and health workers, exercise discretion in implementing policies with limited time and resources. It emphasises how their day-to-day decisions, shaped by workload and professional norms, effectively determine how policies and programmes are enacted in practice.
Complex contagions theory[140]	Complex contagions theory explains how behaviours that require social reinforcement, such as adopting innovations or collective actions, spread through repeated exposure from multiple social contacts rather than through single, weaker ties. In contrast to simple contagions, which spread readily through weak ties (as with infectious diseases), complex contagions rely on strong, overlapping social ties that generate credibility, trust, and normative pressure to adopt new behaviours.

2.5 Ethical approvals and considerations

All components of this thesis received prior ethics approval where required. I led the application to the University of Oxford's Tropical Research Ethics Committee (Reference Number: 519-23). I also submitted several amendments which were required as a result of the iterative nature of realist evaluation data collection and analysis cycles. I was also a named investigator on local approvals from the Human Research Ethics Committee of Northern Territory Health and Menzies School of Health Research (Reference Number: 2022-4479) and the Western Australian Aboriginal Health Ethics Committee (Reference Number: 1237).

Oral informed consent was obtained from all participants. Confidentiality was improved by recording only pseudonymised information in the form of participant role and site number (e.g. FNCHW1 refers to a FNCHW at Site 1), and secure storage on the Menzies School of Health Research institutional OneDrive. The Indigenous Advisory Group guided the cultural governance of the work.

2.6 Reflexivity

This section outlines my positionality as a researcher in relation to this thesis, providing readers with information that enables them to better interpret the work presented.

First, being an embedded evaluator within the implementation team provided richer access to data. This gave me access to day-to-day decision making and informal discussions that would have been less visible to an external evaluator. At the same time, the proximity that enabled these insights also risked more sympathetic interpretations[141]. However, this risk was mitigated by my acute awareness of the responsibility to be open and honest, given the impact on community trust when programmes are presented as more effective or easily implementable than they actually are. Here, my commitment remained firmly focused on the community. More practically, I attempted to mitigate this risk by triangulating data sources and inviting feedback on my interpretations from a range of stakeholders.

Second, my position as a First Nations researcher created opportunities to build rapport that might not otherwise have been possible. When meeting First Nations stakeholders and evaluation participants, sharing my experiences of spending time on Country during yarning discussions allowed participants to establish points of connection, and helped foster relatability. This early rapport meant that in subsequent visits I was able to gain richer insights even in brief conversations during busy work days. However, I am not a member of the specific communities involved, and so faced some of the same limitations as any external researcher, such as my ability to interpret local cultural nuances. Rather than over-interpreting these elements, I acknowledged the limits of my perspective and how this shaped the scope of the evaluation (for further details see Section 7.5 in Chapter 7).

Third, reflexivity extends beyond my own positionality to the broader conditions in which this evaluation was conducted[142]. The screening programme was implemented as part of a trial, and thus was still an artificial environment despite being *closer* to real-world practice. Participation brought additional external implementation activity from the NEARER SCAN study team, visibility, and expectations, with local staff taking on extra tasks related to the programme. However, staffing did not increase, nor were other responsibilities formally reduced, meaning that scanning had to be managed alongside usual workloads. This resourcing dynamic (i.e. additional tasks but limited additional support) may have influenced the implementation of the programme in ways that differ from non-research implementation and should be considered when interpreting the findings.

3

Literature reviews informing implementation design and evaluation

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3.1 Chapter preface

In this chapter, I present two literature reviews. These reviews directly inform the implementation design and evaluation of the echocardiographic screening programme for RHD described in the subsequent empirical chapters. In Part A, I present a narrative review of the implementation of diabetic retinopathy screening in Australia to identify transferable lessons for RHD screening. In Part B, I detail a scoping review of how a Theory of Change approach has been used to design and evaluate other child health service programmes.

This chapter contains content from the following publications:

- **Jones B**, Turner AW, Marangou J, Yan J, Burgess P, Kaethner A, et al. Recommendations for implementing rheumatic heart disease echocardiographic detection in remote Australia: a narrative review and lesson-drawing from diabetic retinopathy screening. *Australian Journal of General Practice.* 2025.
- **Jones B**, Paterson A, English M, Nagraj S. Improving child health service interventions through a Theory of Change: a scoping review. *Frontiers in Pediatrics.* 2023.
- **Jones B**, Nagraj S, English M. Using theory of change in child health service interventions: a scoping review protocol. *Wellcome Open Research.* 2022.

Part A: Narrative review of implementation lessons from a comparable screening programme

3.2 Introduction

Diabetic retinopathy screening provides a useful comparator for RHD screening. Like RHD screening, it introduces imaging technology into primary care and relies on a task-sharing model in which local staff acquire images for off-site interpretation. Diabetic retinopathy is a progressive microvascular complication of diabetes and a leading cause of vision impairment and blindness globally[143]. Early detection through digital fundus photography enables timely intervention and can prevent vision loss.

Screening for diabetic retinopathy in Australia has evolved over the past three decades from fragmented local initiatives to a coordinated national programme. Initial efforts took the form of small pilot projects led by individual health services and research collaborations[144–146]. National recognition of the need for systematic screening followed in 2008, when the National Health and Medical Research Council first recommended annual screening for First Nations people with diabetes[147]. Despite this guidance, screening coverage remained limited, prompting the introduction of two new Medicare Benefits Schedule (MBS) items in 2016 to expand access by providing financial support through the national public health insurance scheme[148,149]. These incremental developments culminated in the establishment of a national, government-funded screening programme in 2018. In this programme, retinal cameras were supplied to 162 primary healthcare facilities, local staff were trained in their use, and telehealth support was provided to improve coverage across remote Australia[150,151].

Screening for diabetic retinopathy shares several features with the echocardiographic screening programme for RHD evaluated in this thesis. Each introduces new screening technology into primary healthcare settings, employs a task-sharing model in which local staff acquire images for off-site interpretation, and seeks to improve screening coverage for conditions that disproportionately affect First Nations communities.

Table 3.1 summarises the screening guidelines for both conditions.

Table 3.1: Summary of the RHD and diabetic retinopathy screening guidelines

Category	**RHD guidelines[66]**	**Diabetic retinopathy screening guidelines[152]**
Mode of acquisition	Echocardiography using handheld echocardiographic devices	Digital fundus photography using retinal cameras
Screening population	Consider for: • Children and young adults aged 5–20 years in high-risk populations • First-degree relatives of index cases • Pregnant women and young adults (aged 21–39 years) in high-risk populations*	• All patients with diabetes mellitus at diagnosis or those presenting 'opportunistically' for optometric review • Children with type 1 diabetes when they reach puberty • Pregnant women with a history of diabetes in the first trimester of pregnancy

*Confirmatory criteria should be applied for individuals aged >20 years, given the limited evidence supporting use of the screening criteria in this population.

My rationale for this review was twofold. First, guidance on developing, implementing, and evaluating complex interventions emphasises the importance of learning from comparable initiatives[109,153]. Second, diabetic retinopathy screening provides a relevant and mature example for RHD screening, having progressed from efficacy testing to national scale-up with established funding. Accordingly, the aim of the work presented in this Part A of Chapter 3 was to identify practical lessons from the implementation of diabetic retinopathy screening to inform the implementation of echocardiographic screening for RHD.

3.3 Methods

A narrative review is a form of literature review that aims to provide a brief synthesis of existing literature on a particular topic[154]. I chose this approach as a pragmatic way to identify implementation lessons, recognising that the evidence was limited and heterogeneous, and that my objective was to derive practical insights rather than to produce an exhaustive account of the literature[155].

A literature search was conducted in the PubMed database on 1 November 2023 using keywords for 'diabetic retinopathy screening', 'Australia', and 'implementation'. The full search strategy was: ((diabetic retinopathy screening OR diabetic eye test OR diabetic retinopathy OR retinal monitoring OR retinal photography OR retinal checks OR diabetic maculopathy) AND (Australia) AND (implementation OR barrier* OR facilitator* OR process OR strategies OR challenges)). Titles and abstracts were screened for relevance, and potentially eligible papers were reviewed in full. Duplicates were removed manually. Grey literature and additional studies were identified through reference list screening.

The inclusion criteria were articles that described, analysed, or discussed the implementation of diabetic retinopathy screening in Australia. Studies of any design and publication year were eligible.

For each included paper, descriptive data (authors, publication year, and key findings) were extracted into a summary table. The findings were then grouped inductively into themes to identify common areas of implementation.

Rose's lesson-drawing framework for public policy[156] informed the analysis, providing a conceptual basis for identifying lessons that could be transferred. The primary mode of transfer was *emulation*, adapting features of diabetic retinopathy screening to RHD screening while accounting for differences.

The preliminary synthesis was developed in consultation with my supervisors, experts in diabetic retinopathy screening and remote Australian primary healthcare policy (identified through relevant publications and existing professional networks), and researchers from the NEARER SCAN study. Input from these individuals helped refine the interpretation of lessons and guided the translation into practical recommendations for RHD screening.

3.4 Findings

The database search identified 549 records, of which eight met the inclusion criteria and were included in the review (Table 3.2). The included studies were published between 2015 and 2023. Analysis of their findings identified seven broad areas of implementation used to organise these findings: training, health promotion, staffing, MBS item numbers, coordination, programme flexibility, and First Nations healthcare implementation.

Table 3.2: Diabetic retinopathy screening implementation studies

Authors (year)	**Implementation areas***
Tapp et al. (2015)[144]	Health promotion
Crossland and Jackson (2017)[157]	Staffing
Glasson et al. (2017)[158]	Training; health promotion; staffing; coordination; programme flexibility; First Nations healthcare implementation
Moynihan and Turner (2017)[145]	Staffing; local coordination strategies
Atkinson-Briggs et al. (2019)[146]	Training; health promotion
Khou et al. (2021)[150]	Training; MBS item numbers; coordination
Watson et al. (2021)[159]	Staffing; MBS item numbers.
Gilden et al. (2023)[160]	Staffing; First Nations healthcare implementation

*The implementation areas emerged from the review. MBS = Medicare Benefits Schedule.

Training

Training was discussed frequently in the included studies. Prioritising the training of local health workers, including FNCHWs, was noted to support a more sustainable model of care[146,158]. In addition, one study reported that 37% of trained staff expressed limited confidence in performing screening and identified a need for supplementary and ongoing training[150]. Finally, the introduction of a structured accreditation process was described as a beneficial quality assurance measure to demonstrate and maintain staff proficiency[144].

Health promotion

Health promotion was addressed across multiple studies. Providing patients with the opportunity to view their retinal images in real time was reported to support engagement in prevention and management discussions[144]. Community awareness campaigns were also used as strategies to encourage participation in screening programmes[159]. One study found that patients preferred means of communication such as phone calls, letters, and text messages, while health professionals instead suggested local newspapers or radio as alternatives due to logistical barriers[146].

Staffing

Staffing was described as an implementation consideration. The importance of identifying and supporting a local champion within each practice to take responsibility and drive implementation was highlighted in multiple studies[145,157,159]. One study underscored the value of adopting a 'whole-of-practice' approach, ensuring that all team members, including administrative and nursing staff, were aware of the programme and its purpose[145]. More broadly, regional coordination roles were described as having a positive influence on implementation[145].

MBS item number

The MBS item number was discussed in relation to programme uptake and sustainability. The existence of the item has been described as important for the implementation of diabetic retinopathy screening, although opportunities remain to improve accessibility[159]. Campaigns to increase awareness of the programme and the MBS item among practitioners and patients were highlighted, including the federally funded KeepSight campaign supported by Diabetes Australia and Bayer[161]. A current limitation is that the MBS item does not apply to individuals with a pre-existing diagnosis of diabetic retinopathy, limiting its use for follow-up screening[150]. In addition, one study suggested that separate billing for image acquisition and off-site interpretation could reduce missed screening opportunities attributable to limited confidence in image interpretation[159].

Coordination

Coordination was described at both clinical and organisational levels. One study identified a perceived lack of onward referral pathways for management following diagnosis[150]. Another reported that informal communication between key programme roles was a strength, but interviewees recommended more formal, regular communication channels (e.g. email groups and videoconferencing), although noted high staff turnover as a barrier[158]. The use of electronic databases, communication software, comprehensive screening forms, and clear treatment guidelines was encouraged[158,160]. It was highlighted that screening results should be sent to the coordinating GP regardless of outcome[158]. Coordination across medical colleges, non-governmental organisations, and programme partners was identified as an important aspect of health system integration[151,161].

Flexibility

Flexibility was highlighted as essential to accommodate local conditions. One study emphasised that service delivery should align with local requirements, and that rigid rules imposed by centrally delivered services can hinder effectiveness and limit outcomes[158]. Local adaptations made in consultation with communities were described as important for supporting effective implementation[158].

First Nations healthcare implementation

Implementation in First Nations settings was described in relation to acceptability and cultural safety. In one study, diabetic retinopathy screening participants (71% of whom identified as First Nations) reported high levels of acceptability attributed to improved access, reduced travel time for eye care, and the simplicity of the procedure[158]. Another study involving ophthalmologists with experience providing healthcare in First Nations communities highlighted the importance of creating a culturally safe environment for screening delivery and of having staff willing to provide flexible service models of care to meet community needs[160].

3.5 Discussion

3.5.1 Recommendations

Seven recommendations for implementing echocardiographic screening for RHD emerged from these findings:

1. Provide regular training for local staff, include formal certification, and incorporate scanning responsibilities into job descriptions.

2. Accompany screening activities with community-focused health promotion and increase awareness of echocardiographic detection of RHD among healthcare staff and community members.

3. Identify programme champions and ensure all staff are informed of the programme.

4. Advocate for MBS billing that separates image acquisition from interpretation, and consider options for ongoing funding to support regular echocardiographic screening for both detection and monitoring.

5. Establish clear referral pathways and formal communication channels, and plan for increased downstream service needs, including confirmatory diagnostic echocardiograms and provision of secondary prophylaxis for confirmed cases.

6. Develop a screening model that can be adapted to each delivery site and foster collaboration through multilateral partnerships.

7. Engage local communities in implementation planning, provide services within culturally safe environments, and involve medical practitioners committed to improving RHD outcomes in First Nations communities.

Interpretation

Implementation experience from diabetic retinopathy screening provides valuable insights into service delivery design and system support. However, the low uptake of diabetic retinopathy screening also offers cautionary lessons. Despite being a more mature, nationally funded programme, a nine-month audit found that only 19 of 132 sites (14%) uploaded images, and in the Northern Territory only 79 First Nations people were screened in 2022–23 despite an estimated 3,477 eligible people living with diabetes[150,162,163]. This highlights the need to anticipate and address barriers to successful implementation[150]. Integration into existing models of care remains a particular challenge. While incorporating echocardiographic scanning into routine work holds promise, lessons from this review suggest that screening for RHD may not be readily absorbed into existing workloads and systems, and will require additional planning and investment in service delivery. During the transition phase, these activities are likely to need dedicated support for coordination and supervision monitoring.

3.5.2 Strengths and limitations

Strengths

A strength of this review was the employment of an explicit lesson-drawing framework to identify implementation lessons. In addition, interpretation was strengthened by collaboration with relevant experts to support translation into actionable recommendations.

Limitations

There are some limitations in the transferability of these findings. Diabetic retinopathy screening is an established, nationwide standard of care in Australia, whereas screening for RHD remains in transition between research and standard of care. Additionally, the acquisition of handheld echocardiographic images is subject to greater variability than digital fundus photography, which may have implications for image quality assurance in a workforce receiving only brief training. Finally, differences in disease distribution mean that RHD screening is likely to be concentrated in remote healthcare facilities, in contrast to diabetic retinopathy screening, which is conducted across Australia.

3.6 Conclusion

In summary, this narrative review identified transferable implementation lessons from diabetic retinopathy screening in Australia, and translated these into seven practical recommendations to inform the design of the echocardiographic screening programme implementation.

Part B: Scoping review of Theory of Change use for design and evaluation of programmes

3.7 Introduction

Part B examines the application of Theory of Change in child health service programmes to determine its suitability for guiding the implementation design and evaluation of the RHD screening programme.

Child health service programmes address the access, use, cost, quality, delivery, organisation, financing, and outcomes of child healthcare services[164,165]. These programmes encompass any organised activity, intervention, project, or initiative that is supported by resources and established to create change for the health of children aged 0–19 years. They may be based in community, primary care, or hospital settings. The echocardiographic screening programme for RHD investigated in this thesis can therefore be considered a child health service programme.

Child health service programmes are often complex, reflecting the involvement of multiple stakeholders (e.g. healthcare providers, parents, and schools) and the pursuit of potentially different objectives across sectors (e.g. health and education). As this complexity becomes more widely recognised among practitioners, researchers, and funders, there is an increasing need to describe how complexity has been considered in the design and evaluation of these programmes.

To respond to this complexity, approaches are needed that clarify how and why programmes are intended to work. Theory of Change, as introduced in Chapter 2, offers one such approach. This scoping review aims to map how Theories of Change have been developed, applied, and refined in child health service programmes.

The review was guided by the following sub-questions:

- How are Theories of Change defined in the literature on child health service programmes?
- What is the rationale for their development in these programmes?
- What processes are used to develop Theories of Change?
- Who is involved in their development?
- At what stage of implementation are they developed?
- How are Theories of Change presented in the literature?
- For what purposes are they used?
- What evidence supports their value?
- How are they refined over time?

3.8 Methods

In this thesis, a scoping review is defined as a form of literature review that aims to map the key concepts, evidence types, and research activity within a defined area of inquiry, particularly where the topic is complex or has not been comprehensively reviewed before[166]. I chose this approach because it enables the rapid and systematic mapping of a broad body of evidence which I anticipated in this review.

The protocol for this review was prospectively registered on the Open Science Framework (DOI: 10.17605/OSF.IO/5TPGM). The review was conducted in accordance with the Joanna Briggs Institute methodology for scoping reviews[167,168], and reporting was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist[169].

3.8.1 Identification of evidence

Eligibility criteria

Table 3.3 outlines the review inclusion and exclusion criteria.

Table 3.3: Eligibility criteria for studies included in this review

Category	Inclusion criteria	Exclusion criteria
Participants	Described a child health service programme* targeting children aged 0–19**.	Focused on obstetric health programmes aimed primarily at maternal, rather than newborn, outcomes. Described programmes delivered exclusively outside healthcare facilities (e.g. school-based programmes). Focused on services delivered solely by non-health social service sectors.
Concept	Described how a Theory of Change (ToC)***, as defined in Chapter 2, was used at any stage (e.g. design, implementation, evaluation). Described the development process of a ToC intended for use. Reported a ToC in narrative or visual form (e.g. ToC diagram).	Reported theory-based evaluation approaches other than ToC (e.g. logic models (as defined in Chapter 2), realist evaluations).
Context	Studies conducted in any country. Any publication year.	–
Sources	Quantitative, qualitative, or mixed-methods designs. Organisational or grey literature (e.g. government, NGO, or private sector ToC documents).	Literature reviews of any kind.
Language	–	Publications not available in the English language.

*Public health programmes (e.g. vaccination activities) were included if delivered by health professionals. **Studies including participants both within and outside this age range were included if the majority (>50%) were aged 0–19 (e.g. 10–22 included; 15–30 excluded). ***Theory-based evaluations are often mislabelled, any study referencing a conceptual framework (e.g. logic model, programme theory, theory of action, results chain) was screened in full. Studies were included only if they explicitly described several defining ToC components.

Search strategy

MEDLINE, EMBASE, Global Health, WHO Global Index Medicus, CINAHL, and SCOPUS were searched from 1946 to present in February 2022 using database-specific search strategies. Grey literature was identified by screening the first 10 pages of a Google search for ‘Child* health* "theory of change" filetype:pdf’.

3.8.2 Selection and extraction

Evidence selection

Citations were imported to EndNote V.20, and duplicates were removed. All titles and abstracts were independently screened against the eligibility criteria by myself and a co-researcher, Amy Paterson, using Rayyan, a review management platform[170]. A screening guide was developed and iteratively refined to support this process (Appendix B.1). I reviewed all eligible full texts, with Amy independently reviewing a random 20%. Any disagreements were resolved through discussion and, where necessary, review by a third researcher, Shobhana Nagraj.

Data charting

Data were extracted from all included studies using Microsoft Excel (V.16.74). The extracted data included: authorship, publication year, study country, programme name, type, and setting. Theory of Change data were also charted, including its definition, development (process, stakeholders, timing), presentation, stated purpose and value, and whether it was refined over time. Finally, the components of the Theory of Change were extracted. In the absence of a gold standard checklist of Theory of Change components, I developed a classification informed by the work of Dhillon and Vaca[171] and Vogel[172], with five components: context, outcomes, rationale, indicators, and assumptions (Table 3.4).

Table 3.4: Theory of Change components

Component	Definition
Context	The circumstances in which the programme operates, including who it is for and where it is delivered, together with the conditions shaping the Theory of Change process, such as who was involved.
Outcome	The changes the programme is designed to bring about, forming the core building blocks of a Theory of Change diagram.
Rationale*	Statements describing why one outcome will lead to another, informed by evidence or experience.
Indicator	Measures (quantitative, qualitative, or informal) used to assess outcome achievement and monitor progress.
Assumption	Conditions beyond the control of the programme implementers that must hold true for the outcomes to be achieved as described.

*I had originally referred to this component as *mechanism* in the scoping review publication related to this chapter in line with other published studies. When writing the thesis I amended this to *rationale* to avoid confusion with the realist conceptualisation of mechanism, which carries a distinct meaning (as discussed in Section 2.3.3).

3.8.3 Data analysis and presentation

The extracted data from the included studies are presented in Appendix B.2. A narrative synthesis was undertaken, structured around the research questions and complemented by inductive thematic grouping to identify recurring themes across studies. Descriptive analysis was also conducted to summarise study characteristics, including study location, type of health service programme, how the Theory of Change was presented, and how it was defined. A checklist of Theory of Change components was applied to support consistency in data charting.

3.9 Findings

3.9.1 Search results

5,354 abstracts and 309 full texts were screened using the eligibility criteria. A total of 38 full texts were included for data extraction and analysis. This process is summarised in Figure 3.1.

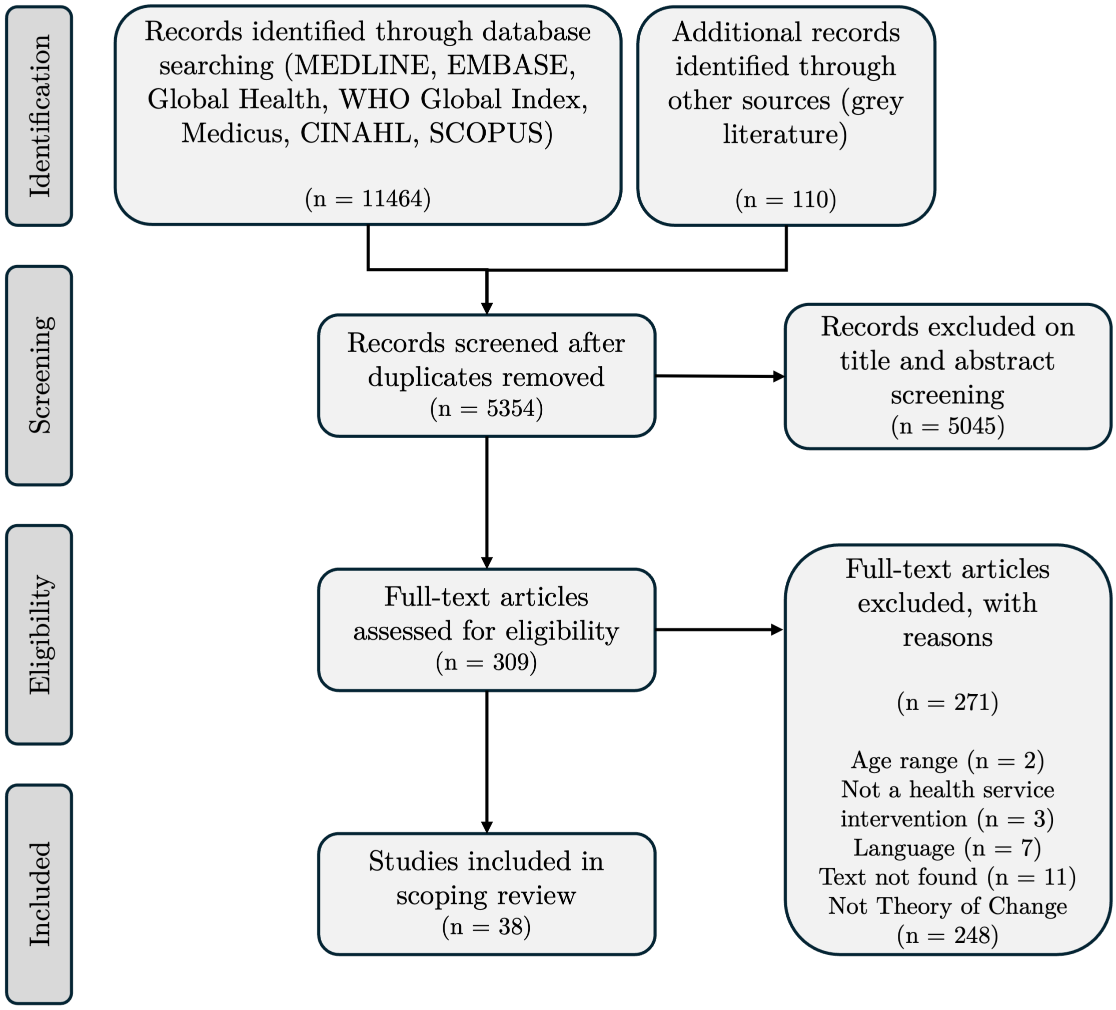

Figure 3.1: PRISMA-ScR flow diagram.

The included studies were published between 2005 and 2022. All were published in the five years prior to the review searches, except one published in 2005[173]. Most studies, 27/38 (71%), were conducted in low- or middle-income countries, eight (21%) were conducted in high-income countries, one (3%) was conducted across both settings, and two (5%) did not report the study setting. The most frequently represented countries were India (eight studies), Ethiopia (five studies), and the United Kingdom (four studies).

3.9.2 Theory of Change findings

Theory of Change definition and presentation

Twenty-four studies (63%) provided a definition for Theory of Change or programme theory (Appendix B.2). The most common elements in the definitions were: 'how and/or why', 'assumptions', 'hypothesis', and 'tool'. 26 studies (68%) described the diagrammatic representation of their model as a 'Theory of Change diagram' with the remainder (32%) describing their diagrams as 'logic models', 'programme theory', or 'causal web diagrams'.

Theory of Change development

Thirteen studies (34%) commented on which stakeholders were involved in the development process. Of these, two involved community members or intended beneficiaries[174,175]. Ten studies (26%) described refinement over time.

Half of the included studies (19/38) reported developing the Theory of Change pre-implementation. Of the remainder, nine (24%) developed it post-implementation, eight (21%) during implementation, and two (5%) did not report clear timing. Under half of studies (16/38, 42%) described the development process, most often as a collaborative approach via workshops, meetings, or discussions. Seven studies (18%) provided a stepwise, more detailed account of the development process.

Theory of Change purpose and value

A justification for adopting a Theory of Change approach was reported in 14 studies (37%). The most common reasons were monitoring and evaluation, testing causal links, and supporting stakeholder collaboration. Sixteen studies (42%) reflected on the value of the approach after use, including using data more effectively, engaging stakeholders, and learning about the programme.

Theory of Change components

Theory of Change components and the frequency of use are reported in Table 3.5.

Table 3.5: Frequency of Theory of Change components

Component	Number of studies in which component was included %
Context	38 (100%)
Outcome	38 (100%)
Rationale	10 (26%) (A further 3 studies mention but do not describe)
Indicator	9 (24%) (A further 7 studies mention but do not describe)
Assumption	10 (26%)

3.10 Discussion

3.10.1 Summary of findings

The development, application, and refinement of Theories of Change are variable across child health service programmes. This echoes the variation reported in Breuer et al.'s[176] systematic review of public health programmes. These variations may reflect the historical emergence of Theory of Change largely outside academia, where pragmatic application may have taken precedence over adherence to methodological guidance. When evaluators use Theory of Change, they may position it either as a theory-driven approach grounded in foundational literature, drawing on work by

Weiss, Rossi, Connell, Kubisch, and Chen[107,120,177], or as a more flexible, practitioner-oriented tool adapted to the needs of a given evaluation. This tension may help to explain the heterogeneity in how Theory of Change is applied and reported across studies.

Another reason for this variation, related to the origins, may be that there is no clear, consistent classification of essential components for a Theory of Change. As mentioned previously, for the purpose of this review, I developed a classification with constituent components. In this scoping review, two components, context and outcomes, were evident in every paper, whereas the other three were present in fewer than a third. These other elements, namely rationale, indicators, and assumptions, arguably differentiate the Theory of Change approach most clearly from more basic logic models, and add depth and explanatory value. Their absence may therefore represent a missed opportunity.

3.10.2 Implications for thesis

I originally considered using a Theory of Change approach to design and evaluate the implementation of the RHD screening programme in this thesis because of its emphasis on stakeholder involvement, as mentioned in Chapter 2. This review confirms that stakeholder involvement is both a common justification for using Theory of Change, and a frequently reported benefit, within child health service programmes.

However, this review also highlights important limitations of relying on a Theory of Change alone. Fewer than a third of included studies reported core elements such as assumptions, indicators, and rationale, which suggests that developing, using, and refining a comprehensive Theory of Change may be difficult in practice. In addition, while the successionist logic that underpins a Theory of Change can be useful for clarifying anticipated sequences of programme outcomes, it often carries implicit assumptions of linearity and causality. For complex interventions implemented within complex systems, change processes are unlikely to unfold in a strictly linear manner. Outcomes may instead depend on interactions between intervention components and local context, including emergent system responses[178,179]. This limits the extent to which a Theory of Change alone can answer the research questions in this thesis, particularly those concerned with explaining variation in implementation outcomes, for example, for whom the screening programme became embedded in everyday practice, to what extent, and under what conditions.

Therefore, in this thesis, I used Theory of Change in targeted ways that aligned with how it was most commonly applied in the included studies and to maximise the reported value. I developed the Theory of Change prior to implementation to structure input from a wide range of stakeholders, with particular emphasis on the perspectives of local stakeholders (Chapter 4). I also used it to support monitoring and evaluation, specifically to define what was intended to be delivered, and to assess fidelity during the process evaluation (Chapter 5). However, for the explanatory component of the evaluation, namely to explain for whom the screening programme could become embedded in everyday practice, to what extent, and under what conditions, I required an approach that emphasises underlying mechanisms and their causal potential. I therefore complemented the Theory of Change with a realist evaluation, another theory-based evaluation approach which is explicitly designed to examine these explanatory questions.

3.10.3 Strengths and limitations

Strengths

A strength of this review was the screening approach. Title and abstract screening was deliberately broad because inconsistent use of Theory of Change terminology meant that restricting inclusion to studies explicitly labelled as 'Theory of Change' would likely have omitted relevant literature. Transparency and consistency were strengthened through a registered protocol, a comprehensive database and grey literature search, and use of a components checklist to standardise data charting.

Limitations

A limitation is the likelihood of reporting and publication bias. Theory of Change may be more likely to be written up, and made publicly available, when it is completed, perceived as successful, or linked to publishable evaluation outputs, rather than when it is abandoned, substantially revised, or used only informally. In addition, Theories of Change may have been developed and used within internal programme documentation that is not publicly accessible, or consistently indexed in a manner that is identifiable through web or publication database search.

3.11 Conclusion

This scoping review mapped how Theory of Change has been used in child health service programmes. It identified common applications, and recurrent gaps in how Theory of Change is developed and reported in this literature. These findings informed how Theory of Change was applied to guide the implementation design and support the evaluation of the RHD screening programme in the subsequent chapters of this thesis.

4

Implementation design of a rheumatic heart disease screening programme

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This chapter contains content from the following publication:

- **Jones B**, Mitchell A, Haynes E, Howard NJ, Wade V, Pears C, et al. Co-designing the implementation of a rural health systems-strengthening rheumatic heart disease program with remote First Nations Australian communities using Theory of Change. *BMC Health Services Research.* 2025.

4.1 Chapter preface

In this chapter, I present a qualitative study of the design process and resulting implementation plans for the RHD echocardiographic screening programme introduced in Chapter 2. This work package was guided by a Theory of Change approach and informed by insights from both reviews reported in Chapter 3. The implementation plans were co-designed with local stakeholders following multiple visits to participating sites, and provide the foundation for the evaluation of the programme presented in Chapters 5 and 6.

4.2 Introduction

The screening programme was designed to be standardised across the five remote First Nations community sites through consistent delivery of its core *functions*, while allowing flexibility in its outer *form* to suit local conditions. *Functions* describe what each programme component is intended to achieve in order to realise the overall aim, whereas *form* describes the site-specific activities through which those functions are enacted in practice. I chose this *function* and *form* framing (proposed by Hawe et al.[180]) because it accommodates community-specific considerations that are critical in First Nations health, while preserving cross-site standardisation, and strengthening the inferences that can be made for future programme scale-up[180,181].

Programme function

The central premise underpinning the screening programme is that training local healthcare workers, including First Nations staff, to perform handheld echocardiography within their own communities can build capacity and improve RHD detection (represented visually in Appendix C.1). Upskilling local healthcare workers in RHD detection may also strengthen informal roles, such as RHD advocacy and education, which could increase RHD awareness across the wider community and support improvements in prevention and treatment. Remote expert review could enable participants with abnormal screening scans to be linked directly to guideline-based RHD clinical care pathways. On the basis of its focus on the local workforce, the programme team anticipated the programme could be sustainable if it became part of routine practice.

This idea, and the programme's core components and functions, evolved organically over several years of collaboration prior to this thesis work, as described in Chapter 2. Table 4.1 summarises the common programme components and functions intended to be delivered at every site.

Table 4.1: RHD screening programme components and functions

Component	Description	Function
Community engagement	Co-design a tailored implementation plan and iteratively adapt the programme in response to feedback.	Maintain meaningful engagement between the programme and the broader community.
Local training	Four days in person training (two theory, two practical) on Single Parasternal Long Axis view with a Sweep of the Heart (SPLASH) abbreviated echocardiographic protocol. Delivered by experts for local FNCHWs, nurses, and GPs, followed by 100 logged scans and a practical assessment.	Develop a trained local workforce capable of performing scans.
Handheld devices	Provision of tablets and handheld probes (approximately one per two scanners).	Ensure functioning handheld devices are accessible for scans.
SPLASH protocol	Use of the evidence-based SPLASH protocol, aligned with World Heart Federation guidelines, which takes 10 minutes and can be performed through the collar.	Acquire interpretable images using the SPLASH protocol.
Image upload	Transfer of studies from tablets to a secure cloud-based image platform, via an app on the tablets provided.	Maintain a consistent and reliable image upload system to enable timely off-site review.
Cardiologist review	Cardiologists interpret scans via the image platform remotely within 72 hours, classify as normal, abnormal, or uninterpretable, provide feedback, and where indicated, recommend repeat screening, a diagnostic echocardiogram (within 3 months), or management.	Support timely off-site cardiologist review, and provide ongoing educational feedback to trained local staff on their scanning.

The programme *form*, however, required the co-design of site-specific implementation plans. This chapter describes the development of these implementation plans for the RHD screening programme in the five remote communities. The specific objectives were to: (a) identify implementation strategies for each site (form), and (b) develop a Theory of Change to explain how and why achievement of the programme's functions, enacted through the support of the locally adapted form, was expected to improve outcomes for people living with RHD in each community.

4.3 Methods

As outlined in Chapter 2, implementation design was conducted between February and June 2023 using a Theory of Change approach. Local Theories of Change were developed in accordance with the Centre for Theory of Change guidelines[182,183]. Each Theory of Change was represented diagrammatically using the Centre for Theory of Change Online software V3.0[184].

4.3.1 Co-design process

Local implementation plans were co-designed with a range of stakeholders in each site including: facility managers, staff considered for training, community leaders, people and families with lived experience of RHD, and representatives from other community services (as detailed in Chapter 2).

The co-design process began with initial community engagement. At one site, this had commenced several years earlier through prior RHD projects. Community engagement officers visited facilities, local Elders groups, and schools where screening may occur, and held informal discussions about the programme. Members of the implementation team then undertook follow-up visits. Each site was visited two to three times before scanner training in mid-2023. Repeated in-person visits supported relationship building and reflected community preferences for sustained engagement.

Prioritising the voices of local First Nations community members was central to the co-design approach because they hold critical insights into what is feasible and effective within their communities. I chose this active prioritisation to mitigate inherent power imbalances between the externally implementing NEARER SCAN study team and local partners. This power imbalance is compounded in some First Nations communities as an ongoing impact of colonisation[185,186].

4.3.2 Data collection summary

Data were collected through participant observational field notes and document analysis of key RHD guidelines and policies (see Chapter 2). During site visits, I, along with six other implementation team members, collected participant observational field notes to inform Theory of Change development. Co-design yarning discussions were conducted through informal and structured group and individual meetings, using a discussion guide (Appendix A.1). As outlined in Chapter 2, yarning is a conversational process of sharing stories that has been formalised as a qualitative data collection method, and is grounded in First Nations worldviews[126].

4.3.3 Data analysis

Data were curated in QSR International's NVivo (V.1.7.1)[187]. A combined deductive and inductive framework analysis approach was used, structured around Powell's list of implementation strategies and the Theory of Change components specified in Chapter 3: context, outcomes, rationale, assumptions, and indicators[188]. I chose this approach because it provides a transparent structure for organising qualitative data, while allowing inductive refinement[189,190]. Thematic analysis was also used to identify patterns in how implementation strategies were described. Data analysis was conducted collaboratively with a qualitative co-researcher from the implementation team, Alice Mitchell. The analysis proceeded through the following stages:

1. **Familiarisation:** Field notes and documents were uploaded to NVivo. Both Alice and I independently read and re-read the data.

2. **Framework development:** A coding framework was developed deductively using the predefined list of implementation strategies and Theory of Change components.

3. **Coding:** Data segments were coded deductively to the implementation strategies list and Theory of Change components, with inductively generated strategies and sub-codes created within each component where appropriate. Inductive coding was used to generate themes described across the implementation strategies.

4. **Charting:** Coded data were charted in a Microsoft Excel spreadsheet. Rows represented outcomes, and columns corresponded to Theory of Change components.

5. **Mapping and interpretation:** Charted data were analysed to identify patterns and relationships to support Theory of Change development, and findings were mapped onto a Theory of Change diagram and sense-checked with local stakeholders.

4.4 Results

4.4.1 Implementation strategies

Across the five sites, 24 implementation strategies were identified through the co-design discussions (Table 4.2). Fifteen strategies aligned with Powell's implementation strategy taxonomy, and nine were identified inductively. Twelve strategies emerged consistently from discussions in all sites. At each site, the strategies are intended to be delivered as a single implementation package.

Table 4.2: Strategies planned for implementation

Strategy	Description	Sites
Assess readiness and identify barriers & facilitators	Assess each site's readiness for training and screening, including implementation barriers and existing strengths.	1–5
Audit & provide feedback	Collect and summarise echocardiographic screening performance data over a defined period to support site-level monitoring, evaluation, and programme modification.	1–5

Table 4.2 – continued from previous page

Strategy	Description	Sites
Build a coalition	Recruit and maintain relationships with local partners, e.g. schools, to support programme activities.	1–3
Celebrate graduation*	Celebrate completion of the training course by holding a graduation ceremony.	1–5
Centralise technical assistance	Develop a centralised WhatsApp system to request and deliver echocardiography technical assistance, with clear pathways for implementation, hardware, and software issues.	1–5
Change physical structure & equipment	Evaluate and adapt physical spaces and equipment, as needed, to support incorporation of echocardiography into routine clinical work.	1–5
Conduct educational meetings	Hold targeted meetings with local stakeholders to inform them about the screening programme.	1–5
Conduct educational outreach visit	Have an expert scanner meet with local providers in clinical settings to provide information about the screening programme.	1–5
Conduct local consensus discussions	Conduct discussions with community members to assess the priority of RHD within the local health agenda and the appropriateness of the screening programme.	1–3
Conduct ongoing training	Plan for and conduct ongoing echocardiography training with local healthcare workers.	1–5
Develop promotional material*	Develop promotional material for the screening programme, e.g. posters and flyers.	1–5
Distribute promotional material*	Distribute locally tailored promotional material throughout the community.	1–5
Identifying piece of clothing*	Provide screening programme shirts for trained local healthcare workers to build professional identity in their clinical role.	1–5
Identify & prepare champions	Identify and prepare funded individuals to lead implementation of the screening programme and address organisational indifference or resistance.	1
Inform local opinion leaders	Inform providers identified as opinion leaders about the screening programme to encourage peer adoption.	1–5
Involve executive boards	Involve existing governance structures in implementation, including review of implementation process data.	1
Progress dashboard*	Develop and display a dashboard to demonstrate progress of the screening programme.	1, 2, 4, 5
Promote network weaving	Identify and build on existing high-quality working relationships and networks within and beyond the clinic and community organisations.	1–5
Provide bags of goods for participants*	Develop and provide small gifts as incentives for participants undergoing echocardiography as part of the screening programme.	4
Provide clinical supervision	Provide ongoing expert support for trained local healthcare workers through remote image review.	1–5
Provide food during screening events*	Provide food for participants and community members during screening events.	1

Table 4.2 – continued from previous page

Strategy	Description	Sites
Provide fun ancillary activities at screening events*	Use ancillary activities to encourage participation in echocardiographic screening, e.g. basketball games.	1
Remind clinicians	Develop a reminder system within local clinic software to prompt healthcare workers to conduct echocardiography.	2
Use mass media	Use local radio to promote the screening programme.	2, 4, 5

*Strategy not on Powell's Expert Recommendations for Implementing Change (ERIC) strategies list and emerged inductively.

The nature of the strategies that emerged during the co-design process can be categorised in three overarching themes:

1. Positive implementation environment

A numbers of strategies were intended to foster a positive implementation environment. These included partnering with local sports teams to deliver screening at matches, engaging professional teams popular in the community to promote early detection of RHD, and using incentives such as bags of goods for children who participate in the screening programme. Strategies suggested to motivate staff included friendly competition supported by a dashboard tracking screening numbers, provision of shirts for trained scanners, and celebrating completion of training through ceremonies informed by local customs alongside formal certificate presentation. The importance of a strengths-based approach to implementation was also inferred from comments to avoid framing the screening programme as a health check and to build on the strengths of the local community.

2. Opportunistic implementation

Strategies supporting an opportunistic, informal, and flexible screening programme were recommended consistently across sites. Stakeholders emphasised the importance of being able to perform screening echocardiography at any time, rather than being restricted to specific consultation types. Similarly, there was a general preference for flexible scanning locations, including clinics, schools, local football matches, and informal home visits. This theme was reinforced by suggestions to deliver RHD education opportunistically alongside the screening programme, to strengthen general community knowledge of RHD.

3. Local languages in implementation

Across implementation strategies, the importance of using local First Nations languages within the screening programme was consistently emphasised. All but one site suggested developing programme promotional materials in the local language. Multiple sites specifically recommended partnering with a local language organisation to support the development of these materials. The use of local languages in training delivery was also highlighted.

4.4.2 Theory of Change

Five locally adapted Theories of Change were developed and articulated in narrative, diagrammatic, and tabulated form. The Maningrida Theory of Change is presented below as an example in all three formats. The site is named in line with the published manuscript, following a decision made in consultation with local stakeholders[191].

Example Theory of Change narrative

In Maningrida, the screening programme will build on long term RHD awareness and engagement with members of the NEARER SCAN study team developed through diagnostic accuracy studies, and an RHD health promotion school module delivered in local languages. RHD care is strongly supported within the clinic, which is the only site with a dedicated RHD building and two RHD-specific nurses. Community willingness to engage with research and to address RHD has contributed to open, productive communication to date.

The plan is to train approximately ten staff members, including several local community members, some of whom participated in earlier iterations of the training as part of diagnostic accuracy studies at this site. Training will be delivered in blocks, with refresher sessions to support familiarity with content and meaningful skill acquisition. The local school and language centre will be engaged to support screening events, facilitating engagement with younger community members and development of contextually appropriate promotional materials. Local staff ownership of the skill will be critical for sustainability, with potential benefits for job satisfaction and broader professional confidence.

Example Theory of Change diagram

As identified in the Chapter 3 scoping review, Theory of Change diagrams can be developed at an operational level and used as a practical planning tool, functioning as a process map. In this study, the site-specific Theories of Change were developed to support local implementation, and therefore specify relatively granular outcomes alongside the other Theory of Change components. Figures 4.1 and 4.2 present the upper and lower halves, respectively, of the Maningrida Theory of Change diagram.[1]

[1] A zoomable version of the full diagram is available online as additional file 7 to the published manuscript[191]: https://doi.org/10.1186/s12913-025-12255-1

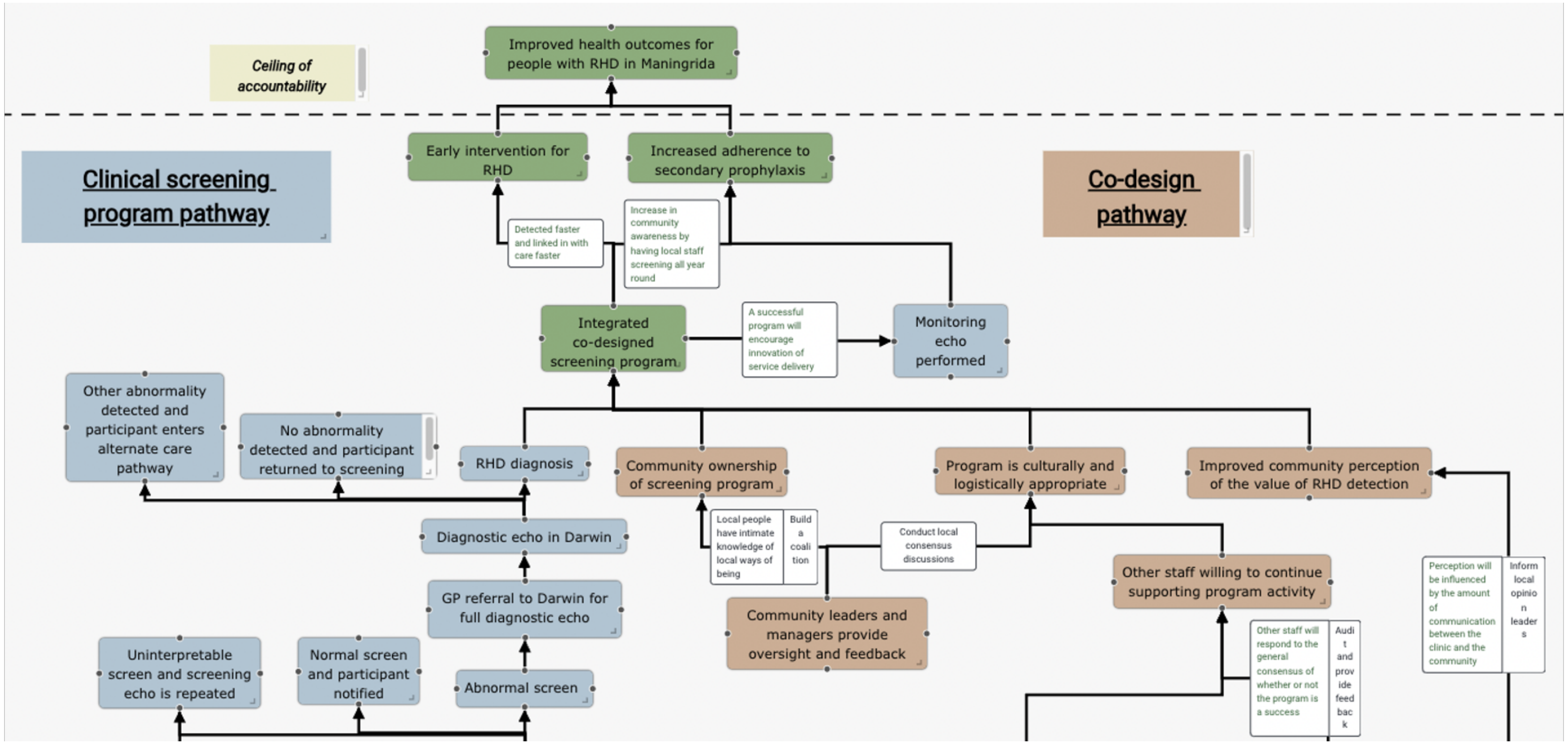

Figure 4.1: Maningrida Theory of Change diagram (top half). Clinical screening programme pathway (blue) = function, Co-design pathway (orange) = form. Green box = long-term outcomes and impact. White box with green text = rationale. White box with black text = implementation strategy.

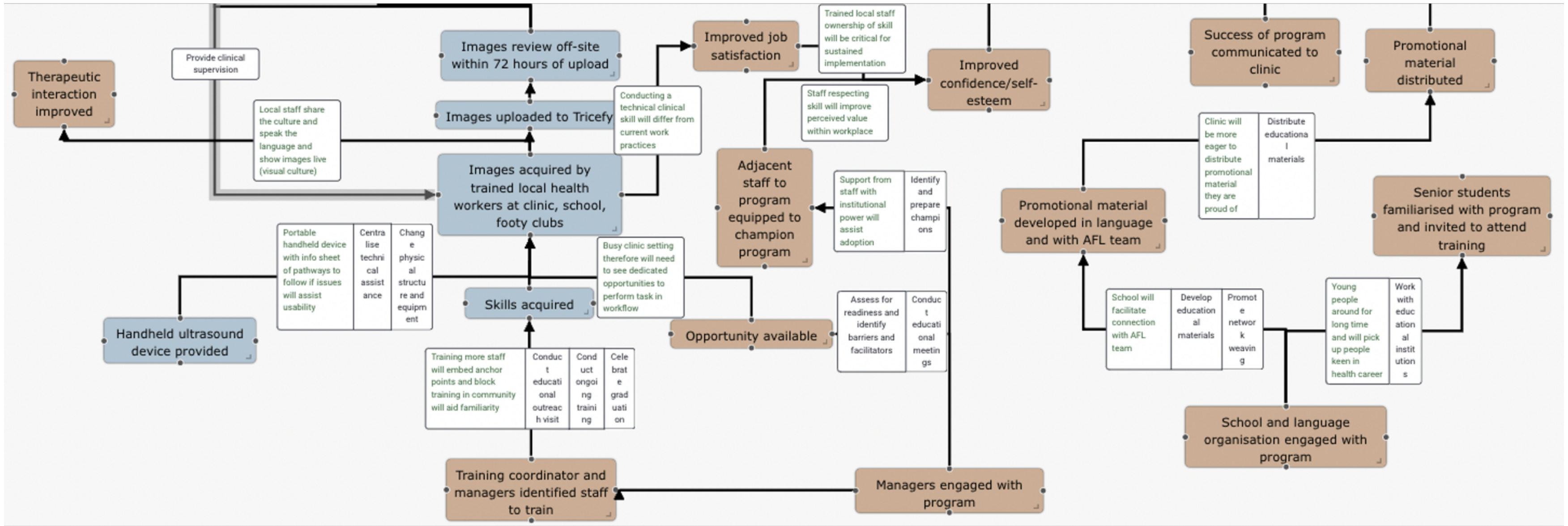

Figure 4.2: Maningrida Theory of Change diagram (bottom half). Legend as above in Figure 4.1.

Example Theory of Change table

Figure 4.3 shows a section of the Maningrida Theory of Change table.

Outcome	Indicator	Rationale	Assumptions	Context
Improved health outcomes for people with RHD in Maningrida	At study completion, gather informal feedback from the whole community		1. Diagnostic echocardiogram is performed in Darwin and interpreted by cardiologist and follow-up appointment with individual is conducted. 2. Stable internet connection to upload image. 3. Adequate supply of secondary prophylaxis. 4. Hardware and software function as planned. 5. Clinic managers will be contactable via email. 6. Culture of learning from previous programmes persists. E.g. Development of the 'Wokforce Development Strategy'.	1. Any screening outreach should be done in the wet season when more people in the town. 2. Collaboration culture. Maningrida has a history of collaboration with Traditional Owners welcoming neighbouring community groups. Important for coordination between the clinic, school, language group, and community. 3. Strong local community involvement in clinic governance and good degree over resourcing decisions. 4. High baseline knowledge of RHD in the community given recent involvement with many RHD programmes. 5. Local ways of being are important for community. Need to consider Male/Female balance for training, ceremony when graduating training course. 6. History of strong FNCHW leadership with long term FNCHW staff. 7. Community with many different language groups. Need to ensure those trained cover these as much as possible. 8. Formalised place-based learning and workforce development plan. 9. Innovation culture.
Early intervention for RHD	At study completion, measure (1) the proportion of the target population prescribed secondary prophylaxis in line with national RHD guidelines, and (2) the proportion of participants diagnosed with RHD	Detected faster and linked in with care faster		
Increased adherence to secondary prophylaxis	At study completion, among people in the community prescribed secondary prophylaxis, measure the proportion achieving 80% adherence over a 12 month period	Increase in community awareness by having local staff screening all year round		
Integrated co-designed screening programme	At study completion, among people in the community with RHD, estimate prevalence and describe the distribution of severity in children and pregnant women.			
Monitoring echo performed	At study completion, gather informal feedback from clinic managers	A successful programme will encourage innovation of service delivery		
Community ownership of screening programme	Yearly, with identified community leaders, undertake a dedicated reflection on who has a sense of ownership over the programme in the community	Local people have intimate knowledge of local ways of being		
Other abnormality detected and participant enters alternate care pathway	-	-		
Programme is culturally and logistically appropriate	Yearly, gather informal feedback from identified community leaders and clinic managers			
No abnormality detected and participant returned to screening schedule	-	-		
Improved community perception of the value of RHD detection	Per quarter, hold informal discussions with community members about the perceived value of RHD detection, led by identified community leaders and clinic managers	Perception will be influenced by the amount of communication between the clinic and the community		

Figure 4.3: Section of Maningrida Theory of Change table

4.5 Discussion

4.5.1 Summary of findings

Co-design across five remote First Nations community sites produced locally tailored implementation plans, with site-adapted versions reflecting small variations in delivery form while maintaining shared core functions. Variation primarily related to the cadre mix and number of staff identified to be trained, community engagement strategies, and local stakeholder involvement. Despite these local adaptations, the planned implementation strategies were largely similar across sites, reflecting the broadly comparable service contexts, and clustered around common themes, including creating a positive implementation environment, enabling opportunistic delivery, and embedding local languages.

Although not always made explicit in the implementation plans, responsibility for enacting strategies was intended to be shared between the external NEARER SCAN study team team and local facility staff. The external team planned to lead ongoing training visits, supervision, and technical support, while local staff were expected to lead facility-level integration and to provide day-to-day encouragement for scanning. As a result, the external implementation team's planned role and support model was broadly similar across sites, with local adaptation concentrated on relationship building, communication, and integration with existing workflows.

4.5.2 Interpretation of findings

The thematic findings can be interpreted using established implementation science theories and frameworks. Given their relevance, I focus in particular on Normalisation Process Theory (NPT)[138] and the Nonadoption, Abandonment, Scale up, Spread, and Sustainability (NASSS) framework[192].

Strategies that supported a positive implementation environment were identified consistently across sites. The programme was considered inherently exciting, because it built local capacity and introduced a novel technology. The implementation approach was therefore designed to deliberately emphasise these positive elements and harness local enthusiasm. In NPT terms, this may support *coherence*, by helping staff make sense of the programme as distinct from other initiatives and by engaging them on the basis of wanting, rather than needing, to participate. From a NASSS perspective, the programme's *value proposition* for local staff lies in upskilling in a community-facing, tangible, and technically advanced technology, which may reinforce this positive implementation environment and reduce perceptions of programme imposition.

All sites recommended strategies that encouraged opportunistic programme implementation. This preference for flexibility may complement the unpredictable cycles of high and low activity that characterise workloads in these remote facilities. For example, trained local healthcare workers may be required at short notice to respond to medical emergencies or to undertake non-clinical roles, such as acting as a driver for the clinic. The ability to perform echocardiography around these demands may therefore be important for programme adoption. In NPT terms, flexibility may support *cognitive participation* by enabling staff to integrate the programme into existing work patterns, rather than competing with them. From a NASSS perspective, flexible implementation may reduce the perceived *extent of change needed to routines* by allowing programme activities to be fitted around existing clinical and non-clinical responsibilities, rather than requiring fixed scheduling or formal reconfiguration of work practices. This may lower the perceived disruption associated with adopting the programme.

Across the implementation discussions, the importance of incorporating local languages into the programme was consistently emphasised. This finding aligns with the *wider system* domain of the NASSS framework. At the level of programme implementation, the proposed involvement of local language organisations in the development of educational materials illustrates an approach that is attentive to wider system influences and seeks to work across organisational boundaries. Such strategies may support implementation by fostering inter-organisational relationships, an element highlighted as important for navigating complexity within NASSS.

4.5.3 Reflections on co-design approach

Resource and regulatory limitations often necessitated compromises within implementation planning, with a risk of unintentionally privileging input from organisations most familiar with these constraints. To mitigate this, I deliberately adopted a Theory of Change co-design approach that encouraged all community participants to propose locally relevant adaptations without initial consideration of feasibility. Proposed strategies were subsequently assessed against resource and regulatory requirements, and ideas that could not be implemented were communicated transparently back to the relevant stakeholders.

Dissemination processes were tailored to each group of stakeholders. For community members, this involved informal face-to-face discussions during subsequent site visits, underscoring the importance of repeated engagement. In some sites, diagrams incorporating locally relevant language and symbols were developed with community members to explain the study and its outcomes. For participating facility managers, dissemination typically occurred through email correspondence and video meetings. For example, a proposal to train staff from a local non-health organisation at one of the sites was deemed unfeasible due to concerns regarding integration with the health system, and this decision was communicated via email.

4.5.4 Strengths and limitations

Strengths

Considerable attention was given to strengthening the validity of the Theory of Change development process. Internal validity was supported through formal qualitative data collection and analysis, including the use of the more culturally appropriate yarning method, investigator triangulation via team debriefs, and involvement of multiple researchers with qualitative expertise. Credibility was further strengthened through face-to-face local stakeholder validation of the adapted Theory of Change diagrams across sites. External validity was supported by using an established implementation strategy taxonomy and Theory of Change guidance and software, and interpreting findings through a formal implementation theory and framework.

Limitations

Theory of Change diagrams were constructed after field visits rather than during workshops with all contributors. While this prioritised yarning, it may have reduced opportunities for real time consensus building, a benefit of the process as highlighted in Chapter 2. Informal, unrecorded yarns were used to support a culturally appropriate and comfortable environment, but this may have limited the completeness of data capture and the ability to verify interpretations. The Theories of Change also reflect contributors' perspectives at a single point in time, while local adaptations were expected to continue throughout the study period. Some co-design discussions were able to be held in a local language at one site. However, most discussions were conducted in English because most of the research team did not speak local First Nations languages, which may have limited the depth of discussions and field notes. Finally, while trust was strengthened through repeated site visits and sustained engagement, cross-cultural communication remains an inherent limitation.

4.6 Conclusion

This chapter described the development of site-specific implementation plans for an RHD screening programme across five sites and articulated the initial Theories of Change. It outlined how the programme was intended to be delivered in routine practice, and why these implementation strategies were expected to support integration and contribute to improved rheumatic heart disease outcomes. The subsequent chapters transition from implementation design to evaluation.

5

Process evaluation of a rheumatic heart disease screening programme

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5.1 Chapter preface

In this chapter, I present the process evaluation of the RHD screening programme. I use five implementation outcomes to assess the variability and extent of implementation success across participating sites. This process draws on the implementation design described in Chapter 4. It also lays the foundation for the realist evaluation presented in Chapter 6, which explains the conditions and causal mechanisms underlying some of the differences in implementation described in this chapter.

5.2 Introduction

Implementation outcomes describe the effects of deliberate and purposeful actions when delivering new programmes[193]. This chapter outlines the assessment of five implementation outcomes: fidelity, adoption, penetration, sustainability, and cost (Table 5.1). These outcomes provide insights into whether the programme was delivered as intended (*fidelity*) and embedded within routine practice (*adoption*, *penetration*, *sustainability*), while also offering practical considerations for future planning (*cost*).

Table 5.1: Definitions of implementation outcomes

Outcome	Proctor et al.'s[193] definition	Operationalised definition
Fidelity*	The degree to which an intervention was implemented as it was prescribed in the original protocol or as it was intended by the programme developers.	*Intervention fidelity* is the degree to which each core programme function was achieved. *Implementation strategies* were delivered to support the achievement of core functions. Some where planned, while others were introduced and adapted throughout the study.
Adoption	The intention, initial decision, or action to try or employ an innovation or evidence-based practice. Also called 'uptake'.	The extent to which trained staff began scanning within the early implementation period.
Penetration	The integration of a practice within a service setting and its subsystems. Also called 'reach' or 'saturation'.	The extent to which scanning was delivered to the intended population.
Sustainability	The extent to which a newly implemented treatment is maintained or institutionalised within a service setting's ongoing, stable operation. Also called 'maintenance', 'continuation', or 'institutionalisation'.	The continued delivery of scanning throughout the study period.
Cost**	The cost impact of an implementation effort.	The cost of the screening programme itself, as well as its implementation.

*In this evaluation, fidelity is not only considered an individual responsibility but also an organisational one. Its assessment therefore extends beyond the individual to the participating facility and NEARER SCAN study team who were also accountable for creating the conditions that enabled or constrained individuals to deliver the programme as intended[194]. **Cost is the least commonly reported implementation outcome[195]. I assessed cost as an implementation outcome, guided by implementation science, rather than undertaking a full health economic evaluation comparing costs and consequences, such as a cost-effectiveness analysis.

I selected these outcomes because they captured key aspects of implementation needed to inform the proposed scale-up of RHD screening in Australia. They are also increasingly highlighted as priorities within implementation science as they are less frequently reported than other outcomes[195,196]. I did not assess the remaining three outcomes from Proctor et al.'s taxonomy (*appropriateness*, *acceptability*, and *feasibility*) as these outcomes were already considered sufficiently supported. The programme's *appropriateness* was supported by the high anticipated burden of undiagnosed RHD at participating sites[73]. *Acceptability* was inferred from the programme's origins, having been developed in direct response to community-identified priorities and its focus on local capacity building. Finally, the programme's *feasibility* was supported by the diagnostic accuracy of the screening model[60] and reinforced through discussions with local stakeholders during the implementation design work (Chapter 4), which indicated that the programme could be operationally viable in real-world settings.

Accordingly, this chapter addresses the following questions:

- **Fidelity:** Were the core functions of the RHD screening programme achieved, and were the planned implementation strategies delivered?
- **Adoption:** What was the initial uptake of the screening programme within the early implementation period?
- **Penetration:** To what degree did the screening programme reach the intended population?
- **Sustainability:** To what degree was scanning activity maintained throughout the study period?
- **Cost:** What were the costs of implementing the screening programme, and how were these costs distributed and influenced by variations in key parameters?

5.3 Methods

The process evaluation methods follow the recommendations outlined by Lengnick-Hall et al.[197]

5.3.1 Data sources

The analysis in this chapter used the data described in Chapter 2. This included both the available primary data (36 realist interviews, seven focus groups, 39 NoMAD surveys, and 200 researcher-days of observation across five sites) and secondary data (programme administrative data and programme activity data).

The costing component used data from multiple additional sources including:

- **NEARER SCAN programme expenditure records:** Direct cost data from project funding reports.
- **Supplier and market prices:** Unit costs of devices and maintenance sourced from price lists, procurement records, and market rates.
- **Wage and workforce data:** Staff remuneration costs based on the classification levels of participating staff, matched to published award rates. Where ranges were available, the median rate was applied for the base case, with minimum and maximum rates used for sensitivity analyses. Personnel costs incorporated a 31% on-cost rate to account for superannuation, leave entitlements, organisational overheads, consistent with *A Costing Guidebook for Implementation Scientists*[198] (details provided in Appendix D.1).
- **Consultation and budget estimates:** Input from NEARER SCAN study team members, facility staff, and programme coordinator to estimate costs not directly captured in expenditure records.

5.3.2 Data analysis overview

Analyses were conducted in July 2025 unless otherwise stated. Quantitative data were analysed in R (V.4.2.2). Descriptive statistics included proportions for categorical variables and medians with interquartile ranges (IQRs) for non-normally distributed continuous data. Means and standard deviations were reported for NoMAD survey domain scores, as skewness values fell within the -1 to $+1$ range, indicating approximately symmetric distributions. Where applicable, associations between variables were examined using Pearson correlation and simple logistic regression analyses, with results presented as correlation coefficients or odds ratios with 95% confidence intervals respectively. A significance threshold of $p < 0.05$ was applied.

For fidelity, both quantitative and qualitative data were relevant. The qualitative data were analysed by programme component (as introduced in Table 4.1 in Chapter 4) using a deductive framework analysis, with illustrative quotes extracted to support findings. These findings were combined with the quantitative data using a parallel convergent mixed-methods approach[199].

Costing analyses were conducted in Microsoft Excel (V.16.74). To assess the robustness of cost estimates, one-way deterministic sensitivity analyses were performed. Cost parameters for each component likely to vary in future implementation were examined. For example, *personnel time* was varied by ±20% to account for uncertainty inherent in retrospective reporting, and *wage rates* were varied between the minimum and maximum published award rates for each actor. For each costing component, low, base, and high estimates were reported. Tornado diagrams were developed to illustrate the relative influence of key parameters on relevant cost components.

5.3.3 Metrics and assessment of each outcome

Fidelity

To operationalise fidelity, I applied Hawe et al.'s[180] distinction between *function* (intervention fidelity) and *form* (implementation strategies), introduced in Chapter 4.

Intervention fidelity

The intervention fidelity assessment was focused on whether each programme component (outlined in Chapter 4) achieved its intended core function (Table 5.2). For example, *staff training* was considered to delivered with 'high fidelity' only if it produced a local workforce capable of performing echocardiography (defined as more than 50% of trainees completing their 100 scans and practical assessment), rather than simply if training sessions were delivered.

Table 5.2: Intervention fidelity assessment

Programme component	Fidelity measure	Low fidelity	Medium fidelity	High fidelity
Community engagement	Qualitative assessment	Minimal	Intermittent	Sustained
Local training	% of trainees completing all training requirements	$<25\%$	25–49%	$\geq 50\%$
Handheld devices	Qualitative assessment of accessibility/function	Frequent issues	Occasional issues	No issues
SPLASH protocol	% of uploaded scans uninterpretable*	$>40\%$	11–40%	$\leq 10\%$
Image upload	Qualitative assessment of upload reliability	Frequent issues	Occasional issues	No issues
Cardiologist review	% of scans reviewed within 72 hours	$<50\%$	50–89%	$\geq 90\%$

* The threshold of $\leq 10\%$ was selected as a readily interpretable benchmark, informed by previously reported non-expert uninterpretable rates[58].

The core function of each of these programme components was assessed at a site level using a three-point scale ('high fidelity', 'medium fidelity', 'low fidelity') based on the relevant Theory of Change outcomes at each site (as described in

Chapter 4) and triangulated qualitative and quantitative data. Where appropriate, pre-specified quantitative thresholds were used to guide ratings. For functions without thresholds, ratings were derived through joint review of the available qualitative data by me and a co-researcher, Alice Mitchell. Theory of Change outcomes were assessed at two time points, approximately six months (December 2023) and 24 months (July 2025) after initial training, enabling assessment of both early and sustained intervention fidelity. Following site visits, each outcome was jointly reviewed by me and Alice Mitchell.

Implementation strategies

The implementation strategy assessment focused on summarising the delivery, adaptations, and contribution of each strategy to the programme components (i.e. describing *form*). This assessment was mainly descriptive, recognising that full adherence to an original plan (Chapter 4) is not always optimal, and that adaptation during implementation is both inevitable and desirable[153,194,200,201].

Adoption

For adoption, programme activity (scan records) and administrative data (training participation records and dates of site visits by NEARER SCAN study team members) were combined to assess three metrics:

1. The proportion of trained staff who performed at least one scan within three months of training;
2. The median time from training to first scan;
3. The median number of scans performed per scanner within the first three months following initial training.

For the purpose of this assessment, the early implementation window was defined as the first three months (of the 24-month evaluation). This was a pragmatic decision based on when initial uptake would be expected following training.

Penetration

For penetration, scan records and Australian Bureau of Statistics data were used to assess the following metrics:

1. The total number of scans of individuals aged 5–20 years;
2. The estimated percentage of eligible 5–20 year olds scanned;
3. The proportion of weeks in which at least one scan was uploaded.

The third metric reflected the NEARER SCAN study team's view that uploading at least one scan per week indicated integration into routine work.

Australian Bureau of Statistics data were specifically used to approximate the number of eligible 5–20 year olds in each community, though these estimates are likely conservative[88,89].

Sustainability

For sustainability, scan records and NoMAD survey data were used to assess:

1. The proportion of weeks in which at least one scan was uploaded during the final three months of the study period;
2. Programme implementer's perceptions of the sustainability of the programme.

The final three month window mirrored the time period used for the adoption outcome, allowing comparison of initial and sustained activity.

I chose to use the NoMAD survey (introduced in Chapter 2 (Appendix A.4)) for this purpose because it is a widely used, psychometrically validated measure of sustainability. Surveys were collected at two time points: during early implementation (December 2023) and late implementation (May–June 2025). Mean scores were calculated for each of the four Normalisation Process Theory construct domains (coherence, cognitive participation, collective action, and reflexive monitoring). The NoMAD survey data were used primarily to triangulate and support patterns identified in the scan activity data, rather than as a stand-alone indicator of sustainability success.

Cost

The cost assessment was informed by *A Costing Guidebook for Implementation Scientists*[198], and reporting adhered to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS), 2022[202]. I was supported in this work by Jeffrey Cannon, a health economist and NEARER SCAN investigator with experience across multiple RHD projects, including prior cost–utility analyses of echocardiographic screening for RHD[63]. Jeffrey and I met weekly during March and April 2025 to discuss the costing approach and continued to meet periodically throughout the remainder of 2025.

Perspective

The costing analysis adopted a multi-provider perspective, reflecting the organisations likely to be involved if the programme were implemented at scale beyond the research setting. The following perspectives were included to inform holistic financial planning:

- **Healthcare providers:** Individual facilities (e.g. ACCHOs or Government primary healthcare clinics) and overarching health bodies who might coordinate the programme across sites (e.g. NACCHO or the state/territory government).

- **Non-healthcare providers:** Schools or other community-based organisations involved in event screening activities. Non-healthcare providers were included because they may incur direct costs related to implementing event-based screening. As the event-based screening model extends beyond clinical settings, incorporating non-health providers ensures a more comprehensive representation of resources.

The costing captured all activities required to implement the screening programme as it operated within the NEARER SCAN study. While research-specific activities were excluded, certain implementation strategies supported by the research team were included because they represented activities that a health service would likely need to replicate or resource to maintain similar programme performance at scale.

Included costs were:

- **Intervention costs:** Training and set-up (e.g. planning, equipment, travel); two different screening models (personnel time for opportunistic or event-based screening); and image review (personnel time for image interpretation).

- **Implementation costs:** Expenditure associated with each implementation strategy.

Excluded costs were:

- **Costs borne by screening programme participants:** For example, opportunity costs such as time lost from work or education.

- **Research related costs:** For example, the implementation design work discussed in Chapter 4, or the evaluation work.
- Costs beyond notifying participants of screening outcomes and updating clinical records.

Cost parameters

Table 5.3 provides an overview of the cost parameters, with further details available in the costing workbook (Appendix D.1).

Table 5.3: Summary of cost parameters

Cost area and component	Cost parameter	Quantity source	Valuation source
Intervention (the screening programme)			
Training and set-up	Person-time: Trainer and coordinators	Self-report (average estimated time)	Award rates
	Person-time: Scanners being trained	Self-report	Award rates
	Equipment including scanning devices and tablets	Study records	Market prices
	Travel and accommodation for training	Study records	Study records
Screening model 1: Opportunistic	Person-time: GP scanner	Self-report	Award rates
Screening model 2: Event-based	Person-time: Nurse and First Nations community health worker (FNCHW) scanners	Self-report	Award rates
	Person-time: Coordinators	Self-report	Award rates
	Person-time: Visiting sonographer	Self-report	Award rates
	Travel and accommodation	Study records	Study records
Image review	Person-time: Cardiologist	Self-report	Award rates
	Person-time: Coordination	Self-report	Award rates

Table 5.3 – continued from previous page

Cost area and component	Cost parameter	Quantity source	Valuation source
Implementation strategies			
Audit and provide feedback	Person-time: Coordination	Self-report	Award rates
Build a coalition	Person-time: Coordination	Self-report	Award rates
Celebrate graduation	Materials: Shirts for trainees as they graduate	Study records	Study records
Change service sites	As per training and initial set-up above	As per above	As per above
Change physical structure and equipment	Equipment: Internet dongles	Study records	Market prices
Conduct ongoing training	Person-time: Trainer	Self-report	Award rates
	Travel and accommodation	Study records	Study records
Develop and distribute promotional material	Person-time: Coordination	Self-report	Award rates
Establish recall systems	Person-time: Coordination	Self-report	Award rates
Identify and prepare champions	Person-time: Champion	Self-report	Award rates

Costing approach

A micro-costing approach was applied to estimate implementation costs. To reduce burden on local stakeholders already involved in multiple research activities, I used a simplified Activity-Based Costing approach[198]. Although a Time-Driven Activity-Based Costing approach could have offered greater precision for personnel costs[203], it was considered unfeasible for this assessment following consultation with Jeffrey Cannon.

The Theories of Change provided a framework for mapping relevant activities. Costing prioritised real-world estimates derived from programme expenditure records. Where data were unavailable, normative estimates were developed using best-practice guidance, such as publicly available salary scales and consultation with the implementation team. Estimates of personnel time were cross-checked with staff involved in the programme's implementation, both at participating facilities and within the NEARER SCAN study team, as personnel time was expected to be the largest cost driver. For non-personnel costs, including travel, accommodation, and equipment, direct cost estimation methods were applied using programme expenditure records or supplier and market prices. All costs are presented in 2025 Australian dollars.

Personnel cost estimation was undertaken through the following steps:

1. **Activity identification:** Fidelity was reviewed against the NEARER SCAN implementation plan to determine which implementation strategies were delivered (see Section 5.4.1). Activities were classified as intervention or implementation components, with corresponding actions, responsible personnel, and time requirements specified.

2. **Input estimation:** For each activity, the frequency and average duration were estimated.

3. **Estimate validation:** Estimates were cross-checked with the cadres who performed the activities.

4. **Resource valuation:** Wage rates were applied to personnel time, and costs were assigned to non-personnel inputs (e.g. travel, accommodation, equipment).

5. **Cost aggregation:** Total and disaggregated costs were calculated by actor, activity, site, and overall programme level.

Assumptions were documented in the costing workbook (Appendix D.1).

5.4 Results

5.4.1 Fidelity

Intervention fidelity

Across all sites, the *programme-in-practice* differed considerably from the *programme-as-designed*. These deviations were primarily driven by issues relating to the handheld devices, image upload, and cardiology review. Community engagement, local training, and the use of SPLASH protocol were delivered as planned in some sites, and with more limited fidelity at others. Relative to one another, Site 2 demonstrated the highest fidelity, followed by Sites 1 and 3, then Site 5, while Site 4 showed the lowest fidelity (Table 5.4).

Table 5.4: Intervention fidelity at each site

Site*	Community engagement	Local training	SPLASH protocol	Handheld device	Image upload
1	Medium	High	Medium	Medium	Low
2	High	High	Medium	High	Low
3	High	High	Medium	Low	Low
4	Low	Low	Medium	Low	Low
5	Low	Medium	High	Medium	Low

*Cardiology review was not site-specific but centrally pooled and had a low fidelity overall.

Community engagement

The core function of maintaining ongoing and meaningful engagement between the programme and the broader community (including local residents, schools, and community organisations) was achieved with high fidelity at Sites 2 and 3, where there were regular informal check-ins. Medium fidelity was achieved at Site 1 with early engagement that was not sustained. Fidelity was low at Sites 4 and 5, where community engagement remained minimal throughout (Table 5.5).

Table 5.5: Community engagement fidelity

Site	Fidelity rating	Engagement	Duration	Fidelity shortfalls	Illustrative data	Relevant ToC outcomes (6m/24m)*
1	Medium	Initial community consultation and dedicated meeting with local Elders; summary of meetings shared back to Elders driven by site champion.	Once-off in co-design phase	No ongoing feedback mechanism despite initial plans to re-engage and general support for programme; future site visits focussed on scanner training.	"We want every child in our community checked for [heart sickness in local language]" [OFN1, relaying a conversation with a local Elder].	Feedback group established (N/N) Partnership with community events (N/Y) School engagement (N/Y) Increased community perception of programme value (Y/Y)
2	High	Informal community check-ins during site visits as per community feedback, leveraging strong existing relationships between clinic staff (including Elders) and the broader community.	Ongoing across study period during field visits	None.	"Talked to senior AHP, teacher from local school, artist at art centre, and group of young boys at the shop. All agreed that the project was important, and many had experience or known about RHD. All positive" [SR2, Sep 2024]. "Positive perception of the clinic we heard in the community, at the art centre, from the council" [OFN2].	Community ownership demonstrated (N/N) Increased community perception of programme value (Y/Y) Engagement of school, sport teams, and local council (P/P) Culturally appropriate programme (Y/Y)

Table 5.5 – continued from previous page

Site	Fidelity rating	Engagement	Duration	Fidelity shortfalls	Illustrative data	Relevant ToC outcomes (6m/24m)*
3	High	Informal check-ins during regular site visits by principal investigators (in their role as visiting specialists), shaped by community preference; strong clinic–community connection and existing relationships.	Ongoing across study period; monthly visits for regular clinics.	None.	"[Principal investigators] familiar with community and well liked here… good links with school and language unit… strong presence of local community members including stalwarts like [a local Elder]" [OFN3].	Community ownership (N/N) Increased community perception of programme value (Y/Y) Community leaders provide oversight and feedback (P/P) School and language centre engagement (Y/N) Culturally appropriate programme (Y/Y)
4	Low	Informal check-ins with community members during visits were facilitated by an investigator with local language skills and long-term relationships. A proposed local group was not formalised.	Intermitter engagement was constrained by staff turnover and absences.	No formal group established; clinic–community uncertainty at the main site made ongoing structured feedback challenging.	"[Local staff member] clearly feeling dejected with the health service…[stating] they didn't listen to her… she would like to leave the service" [SR4]. "Expressed unhappiness among local staff" [SR4]. "Meeting between the AHPs and clinic management to work through AHP unhappiness with clinic" [SR4].	Increased community perception of programme value (NA/NA) School engagement (N/N) Culturally appropriate programme (NA/NA)
5	Low	No community group of local people formed; no local staff at the clinic.	Initial engagement.	Planned RHD steering committee never established by regional health service; no mechanisms for feedback.	"The community feels very 'othered' here… off comments [made] about community" [OFN5]. "Not sure how [the staff] are connecting with people in the community" [SR5].	Increased community perception of programme value (NA/NA) Culturally appropriate programme (NA/NA)

*ToC outcomes vary by site because each site-specific ToC was co-developed with local stakeholders, so outcomes reflect locally agreed priorities rather than a uniform set. ToC = Theory of Change, OFN = observational field note, SR = site report, AHP = Aboriginal health practitioner, Y = achieved, N = not achieved, P = partially achieved, NA = not assessed. Data were selected to illustrate the general tone.

Staff training

Across the five sites, 32 local staff were trained, including 21 FNCHWs, 8 nurses, and 3 doctors. Of these, 23 (72%) were First Nations staff. Fourteen (44%) staff had completed training (performed 100 training scans and passed a practical assessment) by July 2025. The median time to complete training was 14 months (range: 9–21 months). Training was paused or discontinued in some cases due to staff turnover, competing work demands, and extended leave.

The core function of developing a trained local workforce capable of performing scans (i.e. more than 50% of trainees completing training) was achieved with high fidelity at Sites 1, 2, and 3. There was medium fidelity at Site 5 as only one staff member completed the training during the evaluation period (a GP), and a low fidelity at Site 4, where no staff members completed the training (Table 5.6).

Table 5.6: Staff training fidelity

Site	Fidelity rating	Training format	Completion (n/N, %)	Cadres of staff trained	Median time to completion*	Fidelity shortfalls	Illustrative data	Relevant ToC outcomes (6m/24m)
1	High	2 days of in-person training, followed a month later by 2 days of event-screening.	5/7, 71	ALO (n=1) AHW (n=2) AHP (n=1) Nurse (n=1) Midwife (n=1, First Nations) Paediatrician (n=1)	14 months	2 staff (1 AHW and 1 paediatrician) discontinued: one left facility; one was based at a facility where expansion was planned but did not proceed.	"First day of training was so great. Very engaged group and some heartfelt conversations" [OFN1].	Staff identified for training (Y/Y) Skills acquired (Y/Y)
2	High	4 days in-person at Site 3, trained with local staff there.	2/2, 100	AHP (n=1) AHP in training (n=1)	16 months	None.	"Both trained staff keen to create a community of practice [by training at Site 3]" [OFN2].	Staff identified for training (Y/Y) Skills acquired (Y/Y)
3	High	4 days in-person	6/9, 67	CHW (n=5) Nurse (n=4, 1 First Nations)	12 months	1 CHW discontinued after leaving the clinic; 2 CHWs paused training due to competing work constraints.	"Managers here very keen to see the training happen, and for careful thought to be given to who is trained, so that the people who are trained are people who are well placed to continue with scanning and making it succeed and be sustainable in the longer term" [OFN3].	Staff identified for training (Y/Y) Skills acquired (Y/Y)

Table 5.6 – continued from previous page

Site	Fidelity rating	Training format	Completion (n/N, %)	Cadres of staff trained	Median time to completion*	Fidelity shortfalls	Illustrative data	Relevant ToC outcomes (6m/24m)
4	Low	4 days in-person at Site 5	0/10** (6 and then a further 4), 0	CHW (n=1) AHP (n=4) Nurse (n=1) Then, CHW (n=3) GP (n=1)	N/A	1 nurse discontinued after leaving the clinic; 3 AHPs discontinued due to competing work constraints; 1 AHP has training on pause due to leave; 3 CHWs have training on pause due to competing work constraints.	"Very strong steer from the [site 4] community that the right people haven't been trained" [OFN4, Dec 2023].	Staff identified for training (Y/Y) Skills acquired (N/N)
5	Medium	4 days in-person	1/4, 25	AHP (n=2) Nurse (n=1) GP (n=1)***	20 months	1 AHP paused training due to leave.	"Feedback from site 5 scanners: initial training would have been better if site 5 were trained separately from site 4 staff. Combined group too large" [OFN5].	Staff identified for training (Y/Y) Skills acquired (N/P)

*Completion of training was defined as performing 100 supervised scans recorded in a physical logbook and passing both theoretical (at the end of the theory days) and practical assessments (after 100 supervised scans). While most training scans were supervised in person, some were reviewed remotely via the cloud-based image platform, with feedback provided by a cardiac sonographer. **Staff at outreach facility trained Feb 2024, so this site was split into two separate facilities. ***GP had prior external echocardiography training but was integrated early and functioned as a programme scanner. ToC = Theory of Change, OFN = observational field note, SR = site report, Y = outcome achieved, N = not achieved, P = partially achieved, N/A = not applicable, AHP = Aboriginal health practitioner, ALO = Aboriginal liaison officer, CHW = community health worker at a participating facility, GP = general practitioner.

Handheld device

Across the five sites, 12 tablets and probes were made available to trained staff. Three protocol deviations were reported, all involving scanners who were asked by telehealth emergency services to perform urgent echocardiograms in acute settings for non-RHD related care.

The core function of maintaining functioning handheld devices accessible for scanning was achieved with high fidelity at Site 2, medium fidelity at Sites 1 and 5, and low fidelity at 3 and 4 (Table 5.7). Site 1 initially experienced difficulties installing the cloud-based image platform application on purchased tablets, which were later resolved. Site 2 reported no hardware issues and stored the device in an accessible location where it remained charged. Site 3 had persistent problems keeping devices charged, as the tablets held charge poorly and chargers frequently went missing. At Site 4, staff raised security concerns about the devices and therefore stored them in a locked manager's office, which limited accessibility, and they also encountered charging issues. At Site 5, one of the three local scanners consistently reported difficulty accessing the device, which was stored in another scanner's office.

Table 5.7: Handheld device fidelity

Site	Fidelity rating	Number of devices	Operational issues reported	Illustrative data	Relevant ToC outcomes (6m/24m)
1	Medium	4*	Initial issues with downloading cloud review software on clinic tablets; early device set-up problems.	"I know the whole idea is that you can use any [tablet] but clearly you can't because ours aren't working" [CM1]. "Definitely stalled momentum" [OFN1].	Tablet and probe accessible and working (P/Y)
2	High	1	None reported.	"There are no issues with either of them accessing the scanner. They keep it in the manager's office because their consult rooms are used for on call which means there can be numbers of other people in the room. Manager's office is easily accessible" [SR2].	Tablet and probe accessible and working (Y/Y)
3	Low	2	Tablet charging and charger availability issues.	"These machines were being a bit dodgy with the charging… there's been times we had some issues with them, they'd been on charge for days or hours and then they weren't fully charged" [N3]. "Disappearing chargers seem to be a constant issue" [OFN3].	Tablet and probe accessible and working (P/P)
4	Low	2	Security concerns and tablet charging problems; devices sometimes unavailable or stolen.	"At the end of the day you're like 'oh that's not that easy, someone has taken the gel, someone's taken the phone charger'… Little things like that just kind of stress and I'm like ah this is gonna get stolen and like just ends up being a bit more challenging than I thought it would be" [N4]. "All devices dead flat on arrival… by the time it was charged enough [the scanner] seemed to have lost interest" [OFN4].	Tablet and probe accessible and working (P/N/A)
5	Medium	3	Accessibility issues; difficulties obtaining replacement probes from local staff.	"[Scanner] stated that after the initial training they felt confident with scanning but has lost that through not being able to obtain the Lumify [from other staff]" [OFN5].	Tablet and probe accessible and working (P/Y)

*Site 1's probes and tablets were purchased by the clinic. All other sites had their probes and tablets provided by the research institute. CM = clinic manager, OFN = observational field note, SR = site report, N = nurse, Y = outcome achieved, P = partially achieved, N/A = not applicable.

SPLASH protocol

Overall, 13% of reported scans were rated as uninterpretable. Site-level rates of uninterpretable images ranged from 5% at Site 5 to 33% at Site 2. At most sites, no consistent image-acquisition issues were reported. However, at Site 3, difficulties consistently arose in obtaining suitable views of the aortic valve.

The core function of acquiring interpretable echocardiographic studies using the SPLASH protocol (i.e. proportion of uninterpretable scans $\leq$10%) had a high fidelity at Site 5 (5% uninterpretable) and medium fidelity at Sites 2, 3, and 4 (33%, 17%, and 11% uninterpretable respectively) (Table 5.8). The rate at Site 1 could not be formally assessed, as only four scans were reported through the REDCap system (as outlined in Section 5.3.3). The remainder were reviewed on-site by a supervising cardiologist who noted that 'the quality of images [during these visits] was very good overall, but I would still give it around 5–10% uninterpretable rate or needing redirection'. In consultation with this cardiologist, Site 1 was deemed to have achieved medium fidelity to this function.

Table 5.8: Fidelity to the SPLASH protocol

Site	Fidelity rating	Scans rated uninter-pretable (%)*	Notes on protocol adherence issues and image quality	Illustrative data	Relevant ToC outcomes (6m/24m)
1	Medium	N/A%**	N/A. Few training scans reported; most scans completed with in-person cardiologist review.	"Scanners have performed between 70–90 scans and are approaching a standard suitable for practical assessment" [SR1, cardiac sonographer, 8 months after initial training].	Images acquired by trained local health workers (N/A/N/A)
2	Medium	33	Most uninterpretable scans had no reviewer comments; no consistent feedback pattern identified.	None.	Images acquired by trained local health workers (P/P)
3	Medium	17	Common issues: inadequate aortic valve views and missing colour Doppler, particularly on aortic valve.	"I have persistent concerns regarding A's ability to obtain adequate images... B has demonstrated improvement since last time but still requires additional practice scans before practical assessment" [SR3, cardiac sonographer, 8 months after training]. "C was very rusty... D was also quite rusty... B's skills and confidence are growing" [SR3, 12 months after training].	Images acquired by trained local health workers (P/P)
4	Medium	11	Small number of scans flagged; no consistent feedback pattern identified.	None.	Images acquired by trained local health workers (Y/P)
5	High	5	Small number of scans flagged; no consistent feedback pattern identified.	None.	Images acquired by trained local health workers (Y/Y)

*Only a very small number of scans were reported on in REDCap at Site 1, as most scans were completed while a cardiologist was present and reported in person. **This includes both training and recruitment scans reviewed by expert reviewers. SR = site report, Y = outcome achieved, N = not achieved, P = partially achieved, N/A = not applicable.

Image upload

The core function of maintaining a consistent and reliable image upload system to enable timely off-site expert review was had a low fidelity rating at all five sites due to persistent WiFi challenges (Table 5.9). At Site 1, initial difficulties accessing facility WiFi were traced to IP address issues on facility-supplied tablets. At Site 2, delayed scan uploads were common in early 2024 due to connectivity issues. This was partially mitigated by the use of an internet dongle, although the dongle itself had charging issues. Site 3 experienced persistently slow and unreliable WiFi throughout the study, with a back-up option of mobile hotspots also deemed unviable. Dongles were also trialled at Site 3, and the team engaged in regular troubleshooting with local IT support. Site 4 also faced unreliable connectivity but reported less effective engagement with the regional IT team. Uploading difficulties were similarly reported at Site 5.

Table 5.9: Image upload fidelity

Site	Fidelity rating	Upload issues reported	Location of uploading	Illustrative data	Relevant ToC outcomes (6m/24m)
1	Low	Facility WiFi access initially unreliable; IP misrouting when switching between WiFi and mobile hotspot.	Facility	"Again, a lot of time was spent gaining wifi access and uploading studies" [SR1, 7 months after initial training].	Images uploaded to cloud-based image platform (P/Y)
2	Low	Facility WiFi unreliable; replacement dongle occasionally had charging issues.	Facility	"No scans sent from this site since Jan 24 (6 months) due to unable to access internet." [OFN2] "Site 2 wifi was the issue. Hard to do off phone hot spot" [OFN2].	Images uploaded to cloud-based image platform (P/Y)
3	Low	Facility WiFi consistently unreliable; required frequent IP reconfigurations; mobile hotspot unreliable.	Facility	"So frustrating the WiFi issues are a constant issue" [OFN3]. "Scan done 3 days ago but hasn't uploaded yet, still sitting in the queue; impact on turnaround time significant" [OFN3].	Images uploaded to cloud-based image platform (P/P)
4	Low	Facility WiFi access unreliable.	Facility and occasionally at home	"Every time I try and upload scans there are issues" [GP4]. "I was having to take the scanner home, and trying to do it at a friend's house to get internet to send it through" [N4].	Images uploaded to cloud-based image platform (P/Y)
5	Low	Facility WiFi access unreliable.	Facility and occasionally at home	"Can't get on to the WiFi. . . we can't use even our phones to get into this. [FNCHW5] had to take it home to upload" [GP5].	Images uploaded to cloud-based image platform (P/Y)

SR = site report, OFN = observational field note, GP = general practitioner, N = nurse, FNCHW = First Nations community health worker, GP = general practitioner, Y = outcome achieved, P = partially achieved.

Cardiologist review

The core function of ensuring timely off-site cardiologist review and providing ongoing educational feedback to trained local staff was also achieved with low fidelity. Since this programme component was conducted centrally, this assessment is at the programmatic-, rather than site-level. Across all sites, 39% of scans conducted by scanners who had completed their 100 scans and passed their assessment, were reviewed within the protocol-specified 72-hour window (Figure 5.1). The median time from upload to review was 9 days (IQR: 1–33). There was no statistically significant correlation between monthly scan volume and the proportion reviewed within 72 hours ($r = 0.18$, $p > 0.05$). Of the uninterpretable studies, 63% contained educational comments from reviewers; however, no pathway existed for this feedback to be communicated to the scanners.

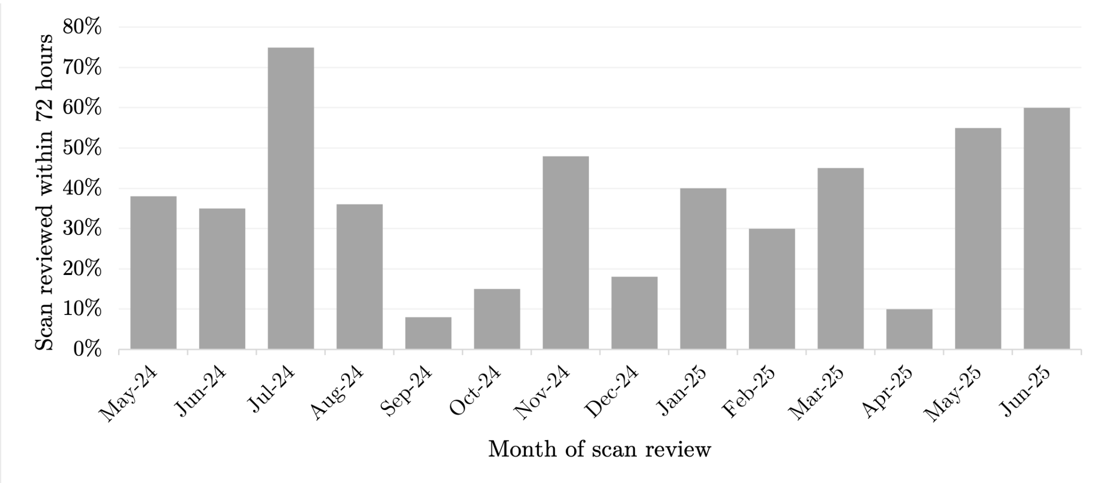

Figure 5.1: Percentage of images reviewed within 72 hours over time.

Implementation strategies

Implementation strategies were delivered to differing extents across sites, with several adaptations and additional strategies introduced in response to emerging local conditions. Key strategies included *ongoing training visits* and *screening events*, which together occurred approximately every 4-6 months across sites (Table 5.10).

Table 5.10: Timeline of training activities

Month	Site 1	Site 2	Site 3	Site 4	Site 5
1 (Jul 23)				Training	Training
2 (Aug 23)		Training	Training		
3 (Sep 23)			Visit		
4 (Oct 23)	Training				
5 (Nov 23)	Event			Visit	
6 (Dec 23)					
7 (Jan 24)		Visit			
8 (Feb 24)		Event*	Event	Event*	
9 (Mar 24)				Training**	
10 (Apr 24)			Visit	Visit	
11 (May 24)	Visit		Visit		
12 (Jun 24)					Visit
13 (Jul 24)		Visit	Visit	Visit	Visit
14 (Aug 24)			Event		Visit
15 (Sep 24)					
16 (Oct 24)				Visit	
17 (Nov 24)					
18 (Dec 24)	Visit			Visit	
19 (Jan 25)					
20 (Feb 25)					
21 (Mar 25)	Workshop	Workshop	Workshop & Event	Workshop	Workshop
22 (Apr 25)					
23 (May 25)		Event			
24 (Jun 25)					

*Denotes a scanner from the site participating that month in a week-long mass-screening programme in another region. During this period, scans were supervised and interpreted in real time by sonographers and cardiologists, and were therefore not uploaded via the usual pathway. **New facility trained. Training = initial four-day training programme comprising two days of theory and two days of practical sessions. Visit = when a cardiac sonographer or cardiologist from the study team visited a site during that month to provide on-site assistance with scanning. Workshop = community-of-practice workshops where scanners gathered from all five sites.

Ongoing training visits, typically of 2-3 days, occurred approximately every few months and provided scanners with opportunities to refresh skills and practise under supervision. Scan activity was markedly higher on days when an expert sonographer or cardiologist was present (OR = 18.15, 95% CI 10.87–30.26, $p < 0.001$). Scanners also described these visits positively:

> "[Visits] definitely helped...it lifts up confidence and gets the momentum going again" [FGGP4].

Screening events were also conducted periodically, creating concentrated opportunities for a high volume of scans. For example, Site 3 held regular screening events, and on event days averaged 8.6 scans per scanner per day compared to 0.1 scans per day on non-event days. Screening events were commonly described as a helpful strategy for creating protected time to complete scans:

> "The scheduled events are much easier for us, it frees up a bit of time" [NE3N(2)].

Conversely, uptake and perceived usefulness of some strategies varied across scanners. *Central technical assistance*, such as WhatsApp groups or scheduled support video calls, were used by only a small number of scanners, most consistently GPs or those who had established working relationships with specific sonographers. These strategies were perceived by some as having limited benefit:

> "Checking in with the scanners [at this site] has not made any apparent difference" [OFN3].

Multiple strategies were introduced or adapted during implementation in response to on-the-ground realities. The aforementioned *screening events* were identified as a formal strategy to support more consistent opportunistic screening. The persistent WiFi connectivity problems prompted a *change in equipment* through the the provision of internet dongles, although these too had limitations:

"The dongle does not hold charge and turns itself off" [OFN2].

Additional training supports were also introduced. These included opportunities to *visit other sites* by enabling scanners to participate in a regional mass-screening week (as part of the Deadly Heart Trek, described in Chapter 1) alongside expert cardiologists and sonographers, and to *capture and share local knowledge* through a centrally located community-of-practice workshop that refreshed skills and facilitated experience sharing. Furthermore, the strategy *change service sites*, was implemented at Site 4 where staff at an additional facility were trained in response to the persistently low scanning activity. A summary of each implementation strategy delivered can be found in Appendix D.2.

5.4.2 Adoption

In total, 55% (17/32) of trained staff performed at least one scan within three months of their initial training. The median length of time from the last day of initial training to first scan was 35 days (IQR 22–182). The median number of scans performed per scanner within the first three months was 1 (IQR 1-4). For site-level findings see Table 5.11 below.

Table 5.11: Adoption at each site

Site	Trained staff scanning within 3 months (n/N, %)	Median days to first scan	Median scans per scanner within 3 months
1	1/7 (14)	163	0
2	2/2 (100)	33	4
3	7/9 (78)	32	3
4	6/10 (60)	5	2
5*	1/4 (25)	321	0

*Site 5 statistics exclude a GP who was integrated into the programme as a scanner but had echocardiography training prior to NEARER SCAN.

5.4.3 Penetration

In total, 360 scans were performed on 5–20 year olds between May 2024 and June 2025, representing approximately 16% (360/2321) of the eligible 5-20 year old population across the sites. This estimate assumes one scan per individual and accurate Australian Bureau of Statistics population records. Of these, 43% (156/360) were done by FNCHWs. Scans were uploaded in 22% (68/305) of weeks during this period. Site-level findings are provided in Table 5.12 below.

Table 5.12: Penetration at each site

Site	Number of scans	Percentage of eligible 5–20 year olds scanned (%)*	Proportion of weeks in which ≥1 scan was uploaded (n/N, %)
1	63	9	3/61 (5)
2	31	28	7/61 (11)
3	120	17	20/61 (33)
4	20	3	7/61 (11)
5	126	85	31/61 (51)

*No denominators are presented to preserve site anonymity. Australian Bureau of Statistics population estimates for ages 5–9, 10–14, and 15–19 years were included for each site. For the Karratha–Roebourne site, the proportion of residents who were First Nations (11.7%) was applied to these age categories rather than using the total numbers, as most residents are not First Nations.

5.4.4 Sustainability

During the last three months of scan activity (April – June 2025) prior to writing, scans were uploaded in 23% (15/65) of weeks. For site-level findings see Table 5.13 below.

Table 5.13: Sustainability at each site

Site	Weeks with ≥1 scan uploaded in final 3 months (n/N, %)
1	0/13 (0)
2	2/13 (15)
3	3/13 (23)
4	3/13 (23)
5	7/13 (54)

Figure 5.2 shows that scan volumes fluctuated throughout the study period. Peaks occurred in May 2024, driven largely by a Site 1 visit, and in March 2025, coinciding with the Darwin workshop, where scanners gathered for additional training, and a screening event at Site 3. Monthly contributions varied across sites. Sites 3 and 5 had relatively consistent activity, with Site 5 scans largely being conducted by one GP. More sporadic activity was observed at Sites 1, 2, and 4.

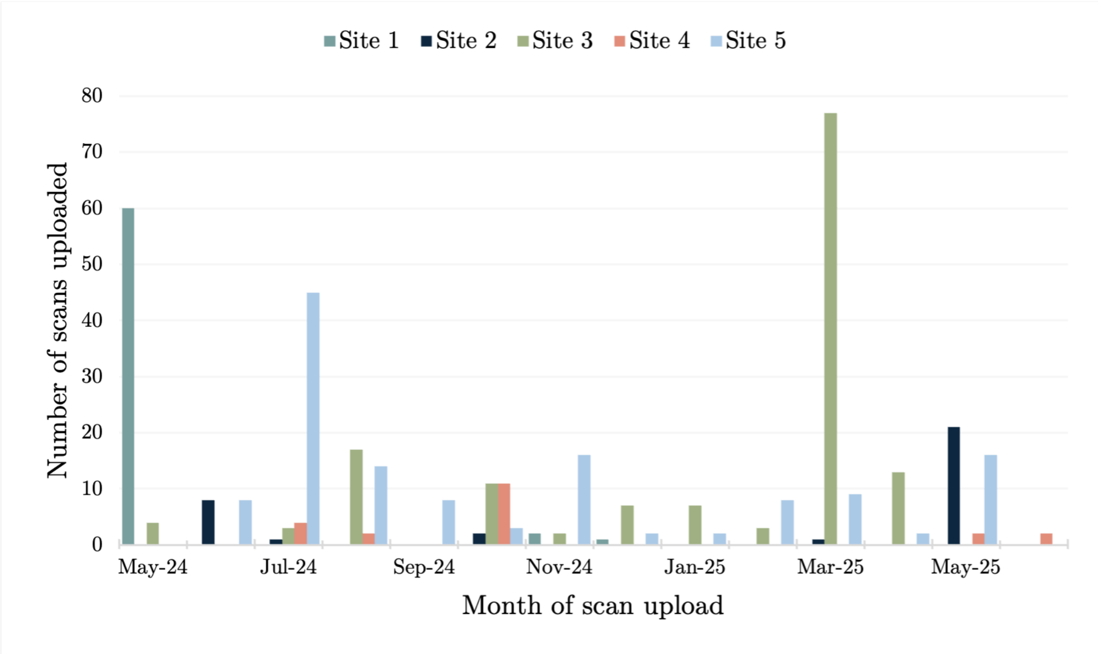

Figure 5.2: Scan uploads over time. All months are shown, with x-axis labels displayed every second month for readability.

As introduced in Chapter 2, perceptions of sustainability can be assessed via the psychometrically validated NoMAD surveys. Thirty-nine NoMAD surveys were collected from implementing staff throughout the study, including 23 responses in early implementation (end 2023) and 16 responses late in implementation (mid 2025). Additional survey participant details are provided in Section 2.4.3.1.

The NoMAD survey groups items into four domains: coherence (sense-making work to understand the programme), cognitive participation (relational work to build involvement), collective action (operational work to enact the programme in practice), and reflexive monitoring (appraisal work to assess and adapt it).

Pooled across sites, mean scores for all domains were ≥ 3.9 out of 5 at both early and late time points, indicating that respondents generally felt the programme made sense, were willing to invest in it, believed it could be enacted in practice, and perceived that it was being appraised and adapted, all despite inconsistent scanning activity. The early cognitive participation score was the highest, with a mean of 4.5 (SD 0.5), demonstrating initial enthusiasm for the programme that declined only slightly to 4.2 later in implementation (SD 0.5). Coherence, collective action, and reflexive monitoring showed a similar pattern, remaining high with only minimal decreases over time (coherence 4.2 to 4.1; collective action 4.0 to 3.9; reflexive monitoring 4.0 to 3.9; SDs 0.5–0.7), suggesting that staff perceptions stayed largely positive even as scanning proved challenging to implement (Figure 5.3). Site-level results are presented in Appendix D.3 and incorporated into the analyses Chapter 6.

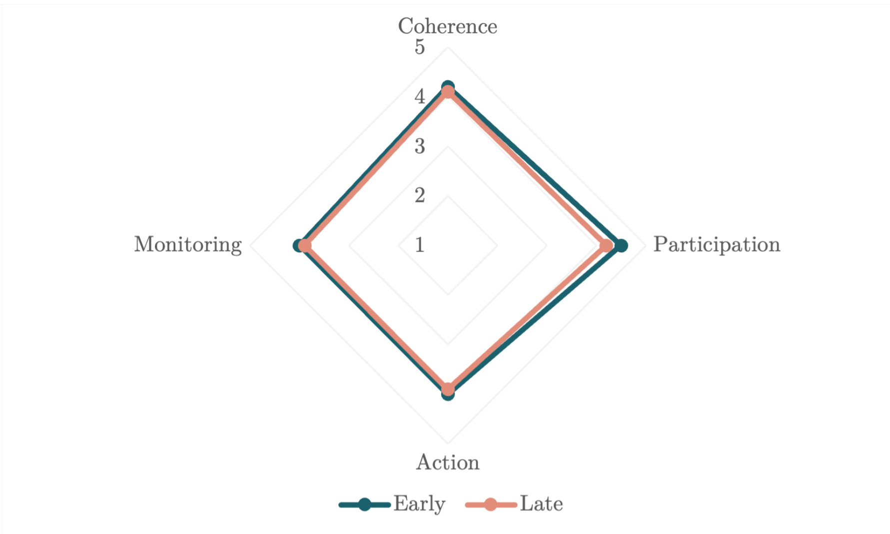

Figure 5.3: Mean NoMAD survey construct scores for each implementation phase.

Cronbach's alpha values were highest for collective action ($\alpha = 0.63$), followed by reflexive monitoring ($\alpha = 0.59$), cognitive participation ($\alpha = 0.50$), and coherence ($\alpha = 0.46$), indicating borderline to poor internal consistency across all domains. In view of this, and the small number of respondents per site and phase (due to the small size of the facilities), these survey findings were interpreted cautiously and considered alongside patterns in the scan activity data.

5.4.5 Cost

Total and component costs

The estimated costs of implementing the NEARER SCAN screening programme across the participating sites is broken down into each cost component in Table 5.14 below (further details in Appendix D.1).

Table 5.14: Estimated costs of implementing the screening programme

Cost component	Total estimated cost
Training and set-up*	AU$51,093 per site
Opportunistic screening model	AU$44.83 per scan
Event-based screening model	AU$90.10 per scan
Image review	AU$49.87 per scan
Implementation package**	AU$9,858 per site per year

*The intial training and set-up for 32 local staff across five sites cost an estimated AU$117,193 in personnel time and AU$32,858 in support costs (including travel and accommodation), totalling AU$138,271. The up-front equipment costs (handheld devices and accessories) and equipment required for one year of scanning amounted to AU$105,413. On a per site basis, the initial training and set-up cost approximately AU$30,010, and equipment costs were AU$21,083, giving a total of approximately AU$51,093 per site. **Assumes an implementation package that includes audit and feedback, engagement with community organisations, graduation celebrations, off-site technical assistance from sonographers, two additional sonographer two-day, one-night site visits in the year, promotional material for events, and the creation of a recall system.

Sensitivity analyses

Training and set-up

The largest cost driver for the training and set-up component was personnel time. Varying personnel time by ±20% changed the total cost by AU$9,375, with total training and set-up costs ranging from AU$46,405 to AU$55,780. The next most influential parameter was wage rate variation, which changed the cost by AU$7,454. Variation in the number of FNCHWs trained resulted in a AU$5,869 change, while variation in support costs (e.g. travel and accommodation) had the smallest effect, at AU$2,619. These results are summarised in a tornado diagram in Figure 5.4.

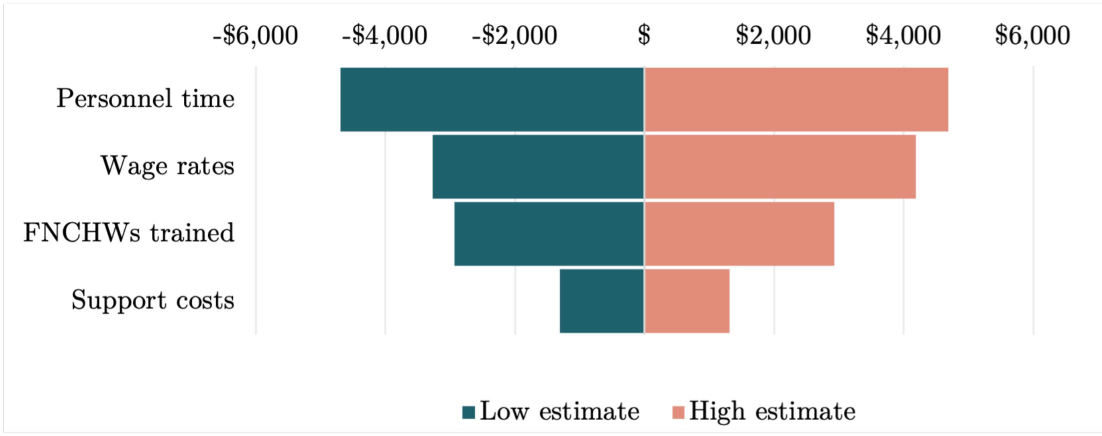

Figure 5.4: Tornado diagram showing results of the one-way deterministic sensitivity analysis for the *training and set-up* cost component. Bars show the change in total cost relative to the base estimate when key parameters were varied individually. Personnel time and support costs were varied by ±20%, wage rates were varied according to the minimum and maximum published award rates for each actor, and the number of FNCHWs trained was varied by ±2 staff from a baseline of four. Amounts are in AU$.

Opportunistic screening model

The opportunistic scanning model was defined as conducting scans during routine healthcare encounters, including child health checks and antenatal visits, and was more closely aligned with the approach originally envisaged during programme design. This model was costed as a GP scanner, reflecting the pattern of scanning activity observed. Varying GP time by ±20% produced a cost range of AU$35.46–AU$53.20 per scan. Separately, applying the minimum and maximum GP wage rates resulted in a range of AU$42.44–AU$53.76 per scan.

Event-based screening model

The event-based scanning model was defined as planned, community-based screening at venues such as schools, community centres, or sports grounds. This model emerged during implementation as a supportive implementation strategy, as discussed further in Chapter 7. For the costing analysis, it was treated as a FNCHW and nurse led model and assumed on-site assistance from two sonographers and an implementation support person, in line with observed practice. The largest cost drivers for this model were personnel time and support costs, each producing a change of AU$18.02 per scan, with total costs ranging from AU$81.09 to AU$99.11 per scan. Varying wage rates between the minimum and maximum published award rates resulted in a AU$15.44 change, while variation in the number of FNCHWs scanning produced the smallest effect, at AU$10.94. These results are summarised in Figure 5.5.

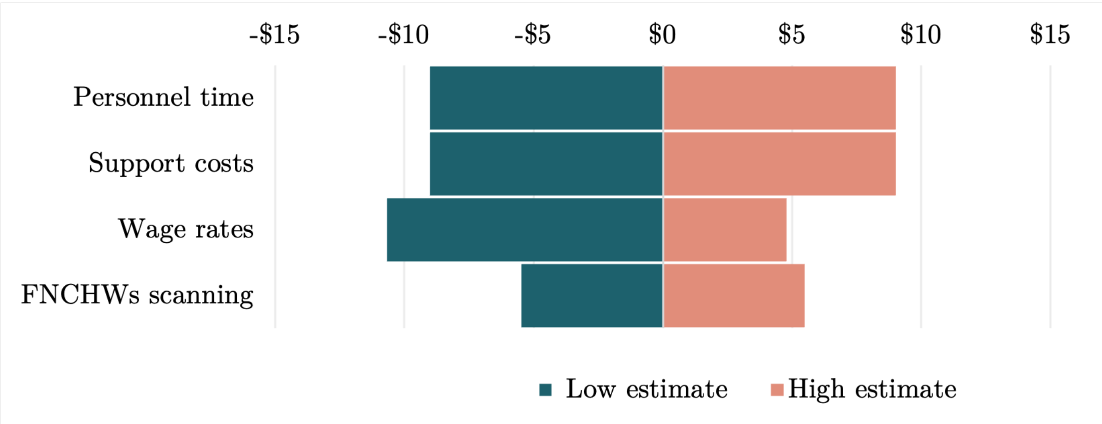

Figure 5.5: Tornado diagram showing results of the one-way deterministic sensitivity analysis for the *screening model* cost component. Bars show the change in total cost relative to the base estimate when key parameters were varied individually. Personnel time and support costs were varied by ±20%, wage rates were varied according to the minimum and maximum published award rates for each actor, and the number of FNCHWs scanning was varied by ±2 staff from the baseline of four. Amounts are in AU$.

Image review

For image review, varying cardiologist time by ±20% produced a cost range of AU$42.92–AU$56.82 per scan. Separately, applying the minimum and maximum cardiologist wage rates resulted in a range of AU$45.78–AU$66.63 per scan.

Implementation strategies

For the implementation strategies, annual costs were most sensitive to the number of sonographer support visits, which changed total costs by AU$8,383, with overall costs ranging from AU$7,067 to AU$12,659. Varying the frequency of audit and feedback cycles resulted in a AU$2,712 change, while adjustments in the frequency of off-site assistance produced a smaller change of AU$1,425. Community engagement meetings had the least influence, with a AU$838 change. These results are summarised in Figure 5.6.

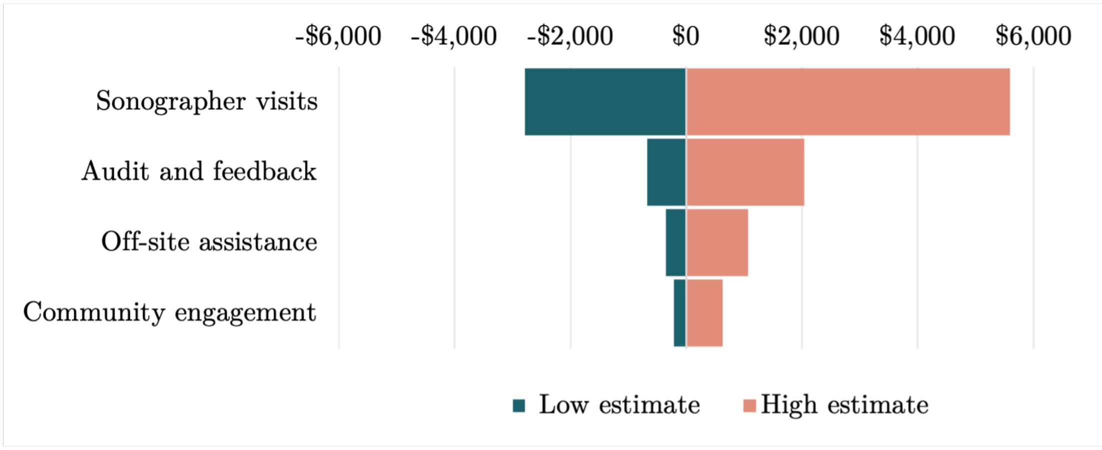

Figure 5.6: Tornado diagram showing results of the one-way deterministic sensitivity analysis for the *implementation strategies* cost component. Bars show the change in total cost relative to the base estimate when key parameters were varied individually. Sonographer support visits were varied from 1 to 3 visits per year (baseline 2), audit and feedback cycles from 6 to 24 per year (baseline 12), off-site assistance from 3 to 12 contacts per year (baseline 6), and community engagement meetings from 1 to 4 per year (baseline 2). Amounts are in AU$.

5.5 Discussion

5.5.1 Summary of findings

Implementation of the NEARER SCAN screening programme in remote First Nations communities was less successful than anticipated at an overall programme level. Fidelity gaps were substantial across key components: handheld devices were often unavailable or uncharged, image uploads were frequently unsuccessful, and off-site reviews were slower than planned. Off-site support was difficult to initiate. Consequently, support was largely provided through on-site visits from NEARER SCAN study team members. Adoption was also slower than expected, penetration was lower, and sustainability remained uncertain.

Alongside these shared findings, the evaluation also identified site-specific differences in implementation. At Site 1, there was strong initial engagement with the programme, driven by the presence of a site champion and early screening events. However, this did not translate into regular scanning, and uploads remained the least consistent of all the sites. At Site 2, both local scanners completed their training, and there was a notably positive relationship between the facility and the local community. Device maintenance was well managed, yet persistent upload problems disrupted scanning. The site also recorded the highest proportion of uninterpretable scans. Site 3 had the largest number of staff complete training and received the most sustained engagement from the NEARER SCAN study team. This translated into the highest consistency of scanning. Implementation was least successful at Site 4 due to issues with all programme components. In response, staff from a second facility within the same community were trained in an attempt to strengthen local capacity. However, no staff at either facility completed training, and only a small number of scans were uploaded. Lastly, Site 5 saw some consistency of scanning but this was almost exclusively due to one GP scanner.

5.5.2 Interpretation of findings

The interpretation of these outcomes is framed against the expectations of the NEARER SCAN study team. These expectations reflect what was thought necessary for the programme to reach those at high risk of RHD but are inherently subjective. Implementation science does not have standardised criteria for what constitutes ‘successful implementation’[195]. While implementation outcomes can indicate progress, success is more accurately viewed as a collection of outcomes whose relative importance differs across programmes and stakeholders[193].

This prompts reflection on whether such findings were, in fact, to be expected from a first attempt at real-world delivery in a notably challenging implementation environment[204]. Diabetic retinopathy screening provides a useful point of comparison. As discussed in Chapter 3, uptake of that programme remained low despite a mature, nationally funded programme, with only 19 of 132 sites (14%) uploading images over a nine-month audit. Taken together, this process evaluation and the diabetic retinopathy screening experience highlight the challenges of programme implementation in these settings.

A Type III error in implementation research occurs when an evaluation attributes a lack of effectiveness to the programme itself, when in fact shortcomings in its implementation meant that it was never truly tested[205]. This process evaluation has allowed for a more informed assessment of the possibility of a Type III error when determining the clinical effectiveness of the NEARER SCAN screening programme (which is in progress and will be reported separately to this thesis as outlined in Chapter 2).

The evaluation of the implementation of the screening programme would not be complete without examining how and why the results reported in this chapter occurred. Were there modifiable reasons why specific sites had difficulties implementing each programme component? Were there conditions in which the programme was successfully implemented, for which scanners, and what caused it to work where it did? Understanding these questions is the task of the next chapter, the realist evaluation. The overall implementation picture presented in this chapter is essential for interpreting the causal explanations developed in Chapter 6.

5.5.3 Strengths and limitations

Strengths

This chapter provides a detailed assessment of implementation outcomes that are often overlooked in evaluations. It draws on longitudinal data collected over an extended period, synthesising large amounts of quantitative and qualitative information. Qualitative and quantitative data were triangulated where appropriate to strengthen the validity of interpretation. The analysis incorporated perspectives from the NEARER SCAN study team, facility staff, and trained local staff across all cadres. Involving co-researchers where appropriate enhanced the understanding and credibility of findings. Finally, by including a costing assessment, this chapter also offers practical resourcing insights for future implementers.

Limitations

The work presented in this chapter had several limitations. First, the fidelity ratings were based on my and Alice's judgement as evaluators and were therefore subject to interpretation. In addition, not all indicators outlined in the original site-specific Theories of Change were assessable due to limited data availability. Only feasible indicators were therefore included, with others recorded as 'N/A' or 'uncertain'.

Second, sustainability, as assessed here, does not capture long-term sustainability. Two years is brief in the context of sustained service delivery, and I came to recognise that meaningful assessment of sustainability is inherently limited before a practice is embedded in routine care (Chapter 6). Nonetheless, it was included to indicate maintained scanning activity, as specified in the original protocol. In the NoMAD survey, internal consistency was below satisfactory thresholds for all constructs, unlike the 'fair' ratings reported previously[133], possibly because items were less applicable in remote First Nations communities.

Third, because scan volume is a readily interpretable indicator of success and this process evaluation did not assess the *impact* of the scanning process itself, the evaluation may have inadvertently privileged volume over quality. This risks under-recognising scanners who completed fewer scans but invested more time into higher-quality scanning interactions.

Finally, the costing reflects a facilitated implementation model, where an external team provided coordination, training, and reporting support. If implemented directly by health facilities, some external costs (e.g. travel and coordination) may decrease, while internal opportunity costs, such as staff time diverted from routine duties, would likely increase. These shifts would alter the cost distribution but not the underlying resource requirements. The costing represents an initial health economics evaluation that will contribute to the development of a budget impact analysis calculator currently being led by Jeffrey Cannon. However, to support the case for a publicly funded Medicare Benefits Schedule item number, a more substantial cost-effectiveness analysis will be required, as discussed further in Chapter 7.

5.6 Conclusion

This chapter provided a process evaluation of the implementation of an RHD screening programme in remote Australia. Across the outcomes assessed, implementation was generally less successful than anticipated. The next chapter explores why this occurred and the conditions under which the programme worked and did not work.

6

Realist evaluation of a rheumatic heart disease screening programme

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6.1 Chapter preface

In this chapter, I build on the process evaluation presented in Chapter 5 by applying a realist evaluation approach. The process evaluation, completed prior to the realist analysis, provided framing on how implementation unfolded across sites and the extent to which it aligned with what was originally envisioned. I begin this chapter by outlining the realist evaluation focus, analytical approach, and overall design. In Part A, I describe the development of the initial programme theory, and in Part B, I report its empirical testing. I conclude by presenting the refined programme theory and discussing how it relates to the existing literature.

6.2 Introduction

The focus of this realist evaluation was to explain how, why, for whom, to what extent, and in what circumstances echocardiographic screening for the early detection of RHD could be embedded into the routine work of FNCHWs in remote Australia. The evaluation was conducted between January 2023 and December 2025. The evaluand was the echocardiographic screening programme implemented in the NEARER SCAN study, in which FNCHWs were trained to use handheld echocardiography to screen for RHD across five remote First Nations communities (further programme details in Chapter 2). The overall purpose of this realist evaluation was to better understand how planned echocardiographic screening programmes for RHD could be implemented in Australia[206] and internationally[66], and how similar new practices might be embedded into the work of FNCHWs.

I adopted a realist evaluation approach because of its focus on generating explanatory insights to support understanding of the implementation of the programme in different settings. I anticipated variation across sites, recognising that differences in workforce composition, facility services, and prior community awareness of RHD were just some of the variable factors likely to shape implementation. I also anticipated that, given the novelty of the programme, it might generate both expected and unexpected outcomes. A realist evaluation provided an approach to explaining these variations systematically and developing context-sensitive insights that could be abstracted into more transferable explanations[98].

The evaluation sought to address the following questions:

- What contextual conditions within remote health facilities shape the embedding of echocardiographic screening into the routine work of FNCHWs?

- What mechanisms influence whether FNCHWs can embed echocardiographic screening into their routine work?
- What intermediate outcomes support the embedding of echocardiographic screening into routine practice for FNCHWs, and how did these vary across sites and over time?
- Overall, what explanatory account best captures how the various contexts, mechanisms, and outcomes interacted to shape the embedding of echocardiographic screening into the routine work of FNCHWs?

To address these questions, I followed the core aim of realist evaluation: to iteratively refine a programme theory into a more plausible explanation. A refined realist programme theory is an explanatory account of how and why a programme works, or doesn't work, for whom, to what extent, in which circumstances (as introduced in Chapter 2).

6.2.1 Analytical process

The evaluation design was guided by the realist evaluation analytical process, which is structured to test and refine a programme theory (Figure 6.1). The evaluation began with the formulation of research questions and preliminary study design, followed by the development of an initial programme theory (defined in Part A). This theory was subsequently tested and refined through repeated cycles of data collection, analysis, and synthesis, with each cycle informing adaptations to the study questions and design. Through this iterative process, a progressively more refined and plausible programme theory was developed (see Appendix E.1 for evolution of questions, design, and programme theory).

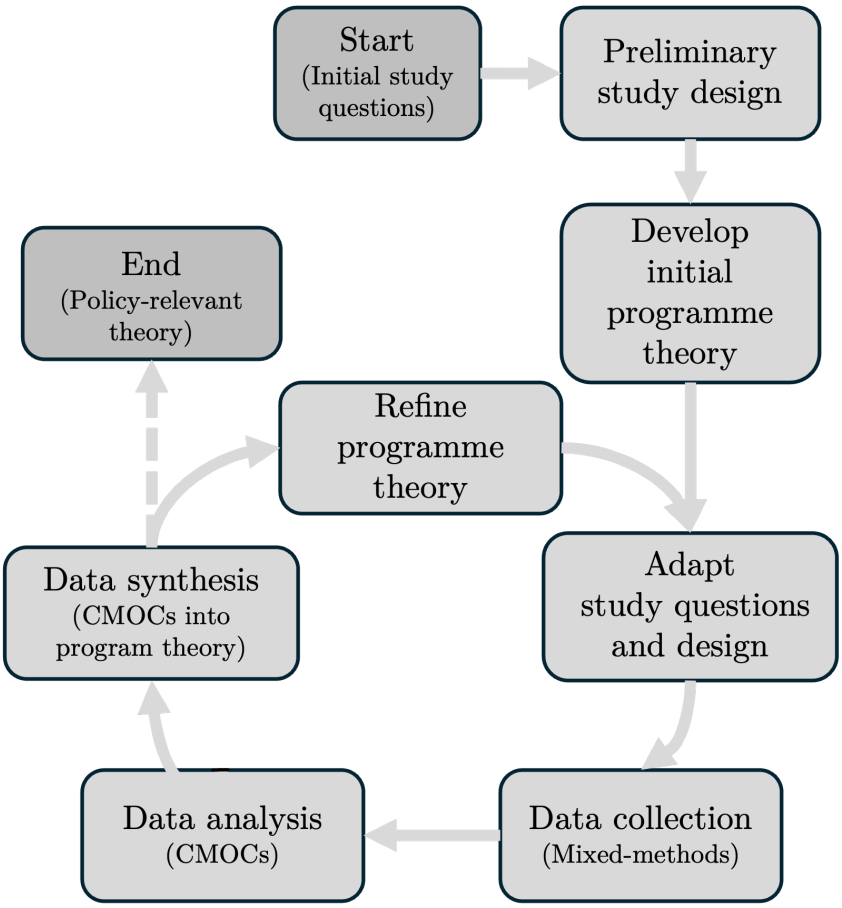

Figure 6.1: Iterative analytical process used in this realist evaluation, adapted from Pawson and Tilley[98] and Marchal et al.[207]. The process illustrates how cycles of data collection, analysis, and synthesis informed iterative refinement of the programme theory. CMOCs = context-mechanism-outcome configurations.

6.2.2 Evaluation design

The final realist evaluation design was informed by this analytical process (Figure 6.2). I used multiple methods to enable triangulation and to accommodate a policy audience of diverse stakeholders who may value qualitative and quantitative evidence differently. From a realist perspective, this multiple-methods approach was valuable because different data types are suited to examining different elements of realist logic (discussed further in Section 6.5.3)[98].

To develop the initial programme theory, a multi-phase approach was used that included a review of the literature, informal interviews with content experts, and iterative evaluation team discussions.

The subsequent empirical testing across three phases employed a multi-site, instrumental case study design (for details on the phases see Chapter 2)[208]. I used a case study design because it enabled in-depth examination in real-world settings. An instrumental design focused the evaluation on understanding the process of *embedding*, and a multi-site design enabled exploration of how variation across settings influenced this process. A realist approach complements case study design because it reorients the focus from generalisability, often considered a methodological limitation of case study research, to the transferability of the programme theory[209].

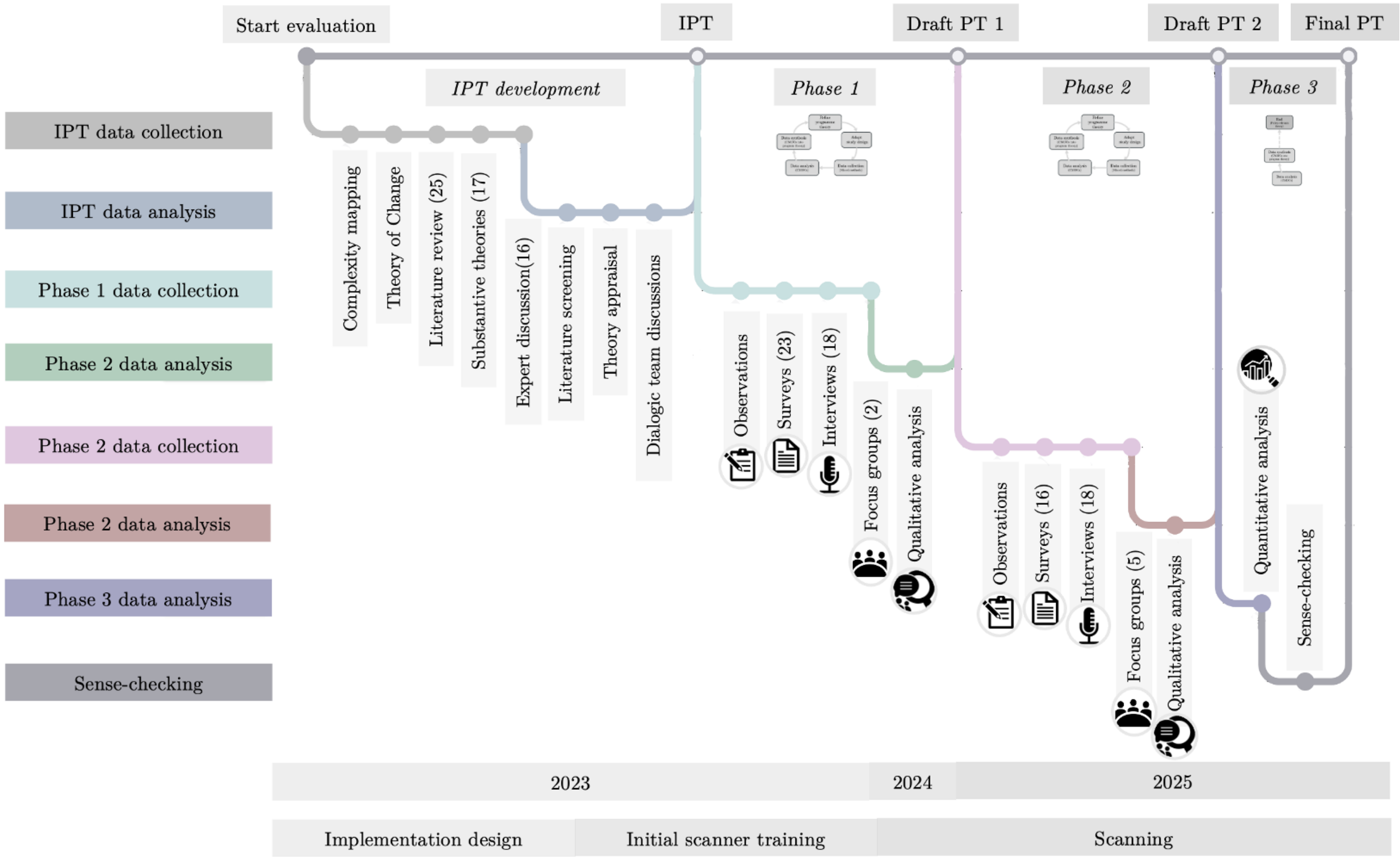

Figure 6.2: Realist evaluation design and timeline showing iterative programme theory development, testing, and refinement across Phases 1–3. Each phase incorporated steps from the analytical process shown in Figure 6.1. PT = programme theory, IPT = initial programme theory. *Limited activity in 2024 reflects a period of study leave undertaken to complete my medical internship.*

Part A: Initial programme theory development

An initial programme theory is an informed but provisional hypothesis about how a programme is expected to cause its intended outcomes[124]. It may or may not be realist in nature[124]. Developing an initial programme theory is often the first step of a realist evaluation. In this thesis, I aimed to develop an initial programme theory that generated informed, preliminary realist explanations to guide the evaluation design and the subsequent empirical testing (Part B).

6.3 Methods

The methodological approach to initial programme theory development in this thesis was informed by the guidance of Shearn et al.[210], Mukumbang et al.[211], and Flynn et al.[212].

Five steps were undertaken as part of this process. These involved: (1) a consideration of the complexity of the programme; (2) the development of a Theory of Change for each site; (3) a review of the literature to identify relevant substantive theories and existing evidence; (4) informal discussions with experts; and (5) the consolidation of findings through discussions within the research team. These steps are presented as discrete stages for clarity of reporting, however, in practice, the process was iterative, consistent with realist principles.

Step 1: Considering complexity

The complexity of implementing the programme was considered through Pawson's VICTORE framework, which provided a structure for reflecting on the interacting elements of volition, implementation, context, timing, outcomes, rivalry, and emergence[213] (Appendix E.2).

Step 2: Theory of Change development

Using a Theory of Change approach, strategic maps were developed with local stakeholders to outline the anticipated sequence of programme implementation and to articulate preliminary ideas about how and why implementation might work. This stage involved a successionist logic of causation rather than a realist logic. This work package is detailed in Chapter 4.

Step 3: Literature reviews

Literature reviews were conducted to identify potentially relevant substantive theories (3a) and existing evidence (both realist and non-realist) (3b). These were used to inform an initial understanding of the programme.

3a: Substantive theories

To identify potentially relevant substantive theories (defined in Chapter 4), a purposive search was undertaken using Booth and Carroll's BeHEMoTh framework (Behaviour of interest; Health context; Exclusions; Models or Theories)[214].

PubMed was searched on 24 January 2023 using a strategy that combined the behaviour of interest and health context with generic theory-related terms: ('screening program*' AND (rural OR remote) AND (indig* OR aborigin*) AND (theor* OR model* OR concept* OR framework*)). To broaden the search, the behaviour-of-interest and health-context elements were sequentially removed from the search strategy. In addition to this search, a standardised list of behaviour change theories was reviewed, and potentially relevant theories from both sources were compiled[215].

Relevant theories were shortlisted for programme alignment and categorised by level; micro (individual), meso (interpersonal), or macro (organisational/system)[210,216].

They were then appraised against three criteria: (1) fit to programme, the extent to which the theory explains the programme's key phenomena (scored 1–3)[210,216]; (2) simplicity, clarity and ease of application (scored 1–3)[210]; and (3) compatibility with realist principles, that is, the capacity to aid understanding of generative causal processes (scored 1–3)[217].

3b: Existing evidence

Two separate literature searches were then conducted to identify relevant realist and non-realist literature.

First, the programme was classified by type to guide the literature review: active case-finding, task-sharing/shifting, rural health, First Nations health, and technology integration.

A manual was developed to guide data extraction (Table 6.1). This approach reflects previous realist work that has used context-mechanism-outcome configuration (CMOC) based manuals to support data extraction and analysis[211].

Table 6.1: Data extraction manual

Category	Definition
Context	Specific conditions (e.g. individuals, interpersonal relations, institutions, and settings) that, when present, enable or constrain mechanisms to be triggered. Programmes change context.
Mechanism	A hidden, context-sensitive, causal force.
Outcome	The intended and unintended changes that occur when a mechanism is triggered in a particular context.
Other	Other relevant information.

PubMed was searched between 25 and 30 January 2023 using a strategy that combined the five major programme types with the term 'realist' in the title or abstract (e.g. ('screening program' OR 'screening intervention') AND ('realist'[Title/Abstract])). Eligibility criteria were then applied (Table 6.2).

Table 6.2: Eligibility criteria for realist literature search

Inclusion criteria	Exclusion criteria
Articles that used a realist approach (evaluation, review/synthesis).	Study protocols, commentaries, or editorials without empirical findings.
Studies relevant to at least one of the five major programme types.	
Published in English and peer-reviewed.	

Non-realist and grey literature were also reviewed to identify relevant information on RHD screening programmes. PubMed, Google Scholar, Google (first 10 pages), the World Health Organization, Global Index Medicus, and Global Health were searched between 6 and 14 February 2023 using the search string 'rheumatic heart disease screening'. Reference lists of included studies were also screened to identify additional relevant sources.

Table 6.3: Eligibility criteria for broader literature and grey literature search

Inclusion criteria	Exclusion criteria
Publications describing or evaluating RHD screening programmes.	Studies focused solely on clinical management or treatment of RHD rather than screening.
Policy documents, reports, or grey literature relevant to RHD screening in community or primary care settings.	
Sources available in English.	

Step 4: Informal expert discussions

Emerging programme ideas were developed based on findings from the preceding three phases and subsequently discussed individually with purposively selected experts to support sense-checking and refinement. These included international experts in RHD screening programmes, and experts in the remote Australian health workforce, identified through academic publications and contacted via publicly available email addresses. A further discussion was held with a senior representative of the National Association of Aboriginal and Torres Strait Islander Health Workers and Practitioners.

To facilitate discussion, the ideas were presented as 'if–then–because' statements. Meetings were conducted throughout March and April 2023, with feedback sought on key considerations and experiential insights that may not have been captured through the literature review.

Two group feedback sessions were also conducted with multidisciplinary teams at the University of Oxford, including members of the Health Systems Collaborative, and the Interdisciplinary Research in Health Sciences group, comprising clinicians, implementation scientists, social scientists, and public health researchers.

Step 5: Team discussions

The final phase involved translating the programme ideas into CMOCs and organising them to construct an initial programme theory. Development of the initial programme theory took place through dialogic team discussions[216] during fortnightly supervisory meetings throughout September and October 2023.

6.4 Results

6.4.1 Provisional CMOCs

The initial programme theory is supported by 16 provisional CMOCs (Table 6.4). These CMOCs were developed drawing on 16 substantive theories (Appendix E.3), 25 published and grey literature sources identified through the formal review (Appendix E.4), additional theories and papers identified through expert and team discussions, and insights from 17 informal expert discussions (Appendix E.5).

Table 6.4: Provisional CMOCs informing the initial programme theory

IPT ID	IPT in CMOC	Supporting sources
1. Introducing the programme to the facility		
IPT1. 'Inform all staff'	If efforts are made to introduce the new role to the entire staff who work as an interconnected team in a small facility (C), the collective awareness that this generates (M), may enable the collective action required to transition service delivery around the new role (O).	Normalisation process theory[138]; planning remote consultations literature[218]; experts[2,4]
IPT2. 'Identify individuals with influence'	If individuals who have influence over practice norms understand and support the programme (C), the exertion of their influence on the broader staff team (M), may promote acceptance of the programme within routine practice (O).	Normalisation process theory[138]; Kotter's 8-step change model[219]; experts[2,3,17]
IPT3. 'Emphasise upskilling'	If the change in practice is presented as a way of upskilling community health workers (C), staff may be more likely to support the change (O), because of a collective sense of responsibility for capacity building (M).	Self-determination theory[220]; structuration theory[221]; coloniality of power theory[222]; community health worker empowerment[223]; FNCHW disempowerment[224]; experts[4,8,17]
IPT4. 'Emphasise safety'	If staff who hold negative preconceptions about the clinical competence of trained scanners in RHD detection are provided with evidence of the safety of the proposed practice change (C), they may be more likely to support the change (O), because they are reassured about its safety (M).	Normalisation process theory[138]; safety and endorsement[225]; experts[9]
2. Training		
IPT5. 'Train multiple people'	If there are colleagues who are also trained in the programme elements (C), direct access to trusted support (M), may allow issues with image acquisition (software, hardware, performing the scan) to be overcome in a timely manner (O).	NASSS framework[192]; psychological safety theory[226]; learnings from other RHD programme in the same setting[227]; experts[1,2,3]
IPT6. 'Train people from community'	To retain knowledge and performance of clinical skills for RHD detection over time (O), training of staff members from the local community should be prioritised (C), due to their connection to their community and the land they are from (M).	First Nations Australian connection to Country[228]; experts[4,8,10,17]
IPT7. 'Conduct low-dose, ongoing training'	If scanners are confident in their capacity to acquire images for RHD detection (C), ongoing belief in their own abilities (M), could lead to continued performance of the task (O).	Ebbinghaus forgetting curve[229]; self-efficacy theory[230]; informal discussions[14,17]

Table 6.4 – continued from previous page

IPT ID	IPT in CMOC	Supporting sources
IPT8. 'Support scanners'	If scanners are supported to take on clinical roles (C), they may be more likely to perform programme adjacent activities (e.g. restocking gel, charging devices) (O), because of a sense that others support their ownership of the scanning role (M).	Normalisation process theory[138]; diffusion of innovations theory[93]; experts[3,4]
3. Conducting scans		
IPT9. 'Avoid early failures'	If scanners successfully acquire images the first few times within their normal working practice by themselves (C), they may be more likely to continue to scan (O), because they have confidence in the workability of the task (M).	NASSS framework[192]; self-efficacy theory[230]; experts[2,3]
IPT10. 'Allow adaptations'	If scanners are enabled to test and adapt the logistics of the new service to their specific work environment (C), staff team acceptability of the service may increase (O), because there is transferring of agency to the scanners who understand their workflow best (M).	Diffusion of innovations theory[93]; diffusion patterns[231]; 'form' and 'function'[180], 'fuzzy boundaries'[232]; experts[5,14]
IPT11. 'Establish protocols'	If a scanner is new to the role of image acquisition, establishing clear protocols (e.g. scan performed during routine check-up) (C), may act as permission and nudge (M), and the images may be acquired more consistently (O).	Schema theory[233]; priming theory[234]; normalisation process theory[138]; COM-B[235]
IPT12. 'Protect time during transition'	If the facility reorganises workflow in response to a change in practice (C), the valuing of the task of RHD detection and the role of the scanner in this process by the broader staff team (M), may lead to adequate time being assigned (O).	Cognitive load theory[236]; experiential learning theory[237].
IPT13. 'Consider job satisfaction'	If the new role involves a tangible, technical skill like echocardiography (C), then the job satisfaction of the scanner may improve (O), because of the respect they receive from the patients and other staff (M).	Job characteristic theory[238]; Point-of-care-ultrasound task-sharing study[239]; experts[4,17]
IPT14. 'Protect roles, consider rivalry'	If the manager or senior GP supports protecting the role for those trained (C), this may lead to enhanced professional confidence for the trained scanners (O), because they are able to maintain their skills through ongoing performance (M).	Task shifting/sharing literature[240,241]; healthcare hierarchy[242]
4. Reviewing images		
IPT15. 'Establish feedback'	If the expert off-site provides constructive feedback to the scanners (C), scanners may be more motivated (O), because they feel supported (M).	Self-efficacy theory[230]; psychological safety theory[226]
IPT16. 'Discuss expectations with reviewers'	If the programme is logistically challenging (e.g. ad-hoc timing of images) within the regular workflow of expert reviewers (C), this may lead to delayed reviews (O), as tasks more distant from day-to-day responsibilities are deprioritised (M).	Cognitive load theory[236]; temporal discounting theory[243]

Informal expert references indicate the corresponding expert listed in Appendix E.5. IPT = initial programme theory, CMOC = context-mechanism-outcome configuration.

6.4.2 Initial programme theory

The initial programme theory proposes that implementation of the programme into routine practice in remote First Nations communities can be supported if the clinical role of the scanners is protected, and the programme logistics are flexible.

Protecting the clinical role of scanners begins with how the programme is introduced to a clinic. In smaller facilities, versatile roles, close working relationships, and overlapping duties amplify each staff member's influence on programme integration. Consequently, staff awareness and perceptions of the scanners' clinical role may shape implementation (IPT 1). Identifying informal leaders who influence team attitudes and ensuring they support the programme may promote its acceptance (IPT 2).

When presenting the programme, it is important to consider which aspects to emphasise. If scanners are professionally disempowered, as FNCHWs in these settings may be, highlighting the programme's upskilling potential may trigger a collective sense of responsibility for capacity building (IPT 3). If staff hold concerns about scanners' clinical competence, emphasising the evidence supporting the model's safety, for example, diagnostic accuracy studies[58,60] or the World Heart Federation guidelines[66], may help build confidence and support (IPT 4).

After programme introduction, trainee selection should prioritise sustaining scanning within the facility. One strategy may be to train multiple staff members, so that scanners have immediate access to trusted, on-site support when issues arise (IPT 5). In smaller communities where screening volumes are expected to be lower, maintaining competence and confidence may be more challenging. While training multiple staff members can provide immediate collegial support, it may also dilute practice opportunities and hinder skill consolidation. It is also important to prioritise training staff from the local community, who are more likely to remain in the role long term because of their connection to the place and people (IPT 6).

From a logistical perspective, low-dose, high-frequency in-person training may suit the constraints of busy remote facilities and help maintain scanners' self-confidence and technical competence over time (IPT 7). Furthermore, fostering a sense of supported ownership over the clinical role could encourage scanners to undertake programme-adjacent activities, such as restocking gel, charging devices, or addressing software and hardware issues (IPT 8).

Following training, local health staff begin performing scans independently. Early success is often pivotal, as initial failures may generate doubts about the workability of the programme and lead to abandonment or deprioritisation of the task in favour of more familiar routines (IPT 9). Empowering scanners to adapt the programme's logistics to fit their workflow might help mitigate early implementation challenges (IPT 10).

The transition to the new role could also be supported by establishing formal protocols and ensuring staff are allocated sufficient time to perform scans. Such protocols may serve as an informal endorsement and form of permission for trained staff (IPT 11), while protected time signals institutional valuing of the task within daily practice (IPT 12).

The technical and specialised nature of scanning may enhance job satisfaction for those trained, owing to increased respect from colleagues and patients (IPT 13). However, this same interest may create vulnerability if new or transient staff (e.g. rotating GPs) assume responsibility for scanning, disrupting the developing role integration. When these staff depart, the facility may be left without anyone confident to continue scanning (IPT 14), a particular concern given the high turnover typical of remote Australian facilities.

The off-site review of images by experts may also shape programme integration. Constructive feedback from reviewers could help sustain the motivation of scanners (IPT 15). Establishing formal governance structures to coordinate this interaction may further strengthen accountability and consistency. However, because tasks aligned with day-to-day responsibilities are often prioritised over more distant, ad-hoc tasks, it is important that expert reviewers are clearly informed of their expected turnaround times. Delays in feedback may discourage scanners, who could become disheartened and less inclined to continue scanning (IPT 16).

Overall, this initial programme theory provided the foundation for empirical testing and subsequent refinement of the programme theory in Part B.

Part B: Programme theory empirical testing

The purpose of Part B of the realist evaluation was to empirically test the initial programme theory in order to confirm, refute, or refine it into a final programme theory that is both plausible and transferable.

6.5 Methods

The empirical testing of the programme theory built on the multi-site case study design described earlier in this chapter. This methods section outlines the realist specific analytical processes used to test and refine the programme theory through successive phases of data collection and analysis. In reporting this work, I considered the RAMESES II standards for realist evaluation[124].

6.5.1 Data collection summary

The data sources and collection methods are described in detail in Chapter 2. To summarise, the analysis presented in this chapter drew on a dataset that included 36 realist interviews, seven realist focus groups, and 39 Normalisation MeAsure Development (NoMAD) surveys, all collected from staff implementing the programme across the five sites. It also included 200 researcher-days of observation over 24 months, which generated 224 pages of fieldnotes. In addition, the dataset incorporated secondary quantitative data, including usage data on 360 echocardiographic scans from programme activity records, as well as programme administrative data on site visits, scanner cadre, and training progress.

6.5.2 Trustworthiness of data collection

Several strategies were used to enhance the trustworthiness of data collection[124]. Triangulation involved combining qualitative and quantitative methods and collecting data from multiple perspectives, including staff in different roles and across sites. This approach supported the development of a more complete account of implementation rather than isolated perspectives. Data were collected longitudinally over 24 months to capture the natural fluctuations typical of remote facilities with high staff turnover and operational variability. The extended observation period helped distinguish transient disruptions from more stable patterns[244]. Consistent with realist principles, I recognise that the resulting programme theory is inherently temporally bounded[213].

As an embedded evaluator, I collected observational data alongside NEARER SCAN study team members who were also assisting with implementation, allowing both implementation and evaluation perspectives to inform the analysis. Repeated site visits enabled rapport with staff and a deeper understanding of local environments, while reflexive journaling and supervisory discussions helped maintain analytical distance.

As detailed in Chapter 2, the NoMAD survey was adapted for local comprehensibility following feedback from a site manager, consistent with accepted guidance on its local adaptation (Appendix A.4)[133]. Interview and focus group guides were also refined to reflect participants' roles, experience, and the stage of theory refinement (Appendix A.2)[131,132]. All interviews and focus groups were audio-recorded and transcribed verbatim, and quantitative datasets were checked and cleaned for completeness prior to analysis. Ethics approval was obtained as detailed in Section 2.5.

6.5.3 Data analysis

Data were analysed using a realist logic of analysis. Throughout the analysis, several reasoning approaches were applied. To identify relevant context and outcome patterns, inductive reasoning derived directly from the data, and deductive reasoning informed by the emerging programme theory and CMOCs was also used. The exploration of underlying mechanisms drew on a combination of abductive and retroductive reasoning. Abduction involves creative, interpretive thinking in which the evaluator generates the most plausible explanations from incomplete data[245]. Retroduction, refers to the reasoning process of identifying causal forces that may lie hidden beneath observed patterns[246].

Phase 1 analysis

For the analysis of primary qualitative data collected during Phase 1, a stepwise, realist-informed process was followed[247].

1. **Familiarisation and sorting:** Interview, focus group, and observational data were uploaded to the Menzies School of Health Research SharePoint in Microsoft Word format. Each transcript and set of fieldnotes was reviewed to identify excerpts relevant to programme implementation or to the initial programme theory. Relevant data were assigned inductively to 'conceptual buckets' representing emerging ideas. Some excerpts were moved between conceptual buckets during this step, or assigned to multiple buckets where their meaning was relevant to more than one idea.

   Data from each site were read and sorted separately and sequentially to build a grounded understanding of each participant's experience and to develop site-specific explanations of how and why implementation unfolded as it did. This approach also helped reduce the influence of dominant voices or data-rich sites. Comparative analysis was then used to examine patterns of convergence and contradiction across sites, with attention to methodological rigour when adjudicating competing interpretations.

This step was conducted by me and a senior qualitative researcher from the NEARER SCAN study team, Alice Mitchell, to enhance trustworthiness through investigator triangulation. As Alice was new to realist work, I provided an introduction, and we met weekly to discuss coding and interpretations.

2. **CMOC development:** Following familiarisation, it was determined between Alice and me that sufficient data had been gathered to begin developing draft CMOCs and to confirm, refine, or refute those proposed in the initial programme theory. Emerging CMOCs were generally developed by working backwards, starting with the outcome, then identifying potential mechanisms and contextual features. Where mechanisms could not be directly inferred from the data through retroduction, substantive theories identified during the initial programme theory development were used to inform interpretation.

3. **Interim programme theory development:** The refined CMOCs were grouped into general domains and summarised narratively to produce the first iteration of the draft programme theory (Appendix E.1). At this stage, the theory remained exploratory and descriptive rather than being positioned at the middle range, and CMOCs were not yet ordered sequentially.

Phase 2 data analysis

In Phase 2, CMOCs were directly refined using the additional data collected, with each dataset again analysed individually and sequentially. Data analysis was primarily deductive, using each existing CMOC as a guiding framework to assess whether it was confirmed, refuted, or required refinement. Where new CMOCs emerged, the same stepwise process described in Phase 1 was applied.

During this phase, the analysis expanded to consider subgroups beyond site or cadre, such as scanners from the local community compared with those from elsewhere, and FNCHWs with differing levels of qualification.

Phase 3 data analysis

Quantitative data were used to triangulate and refine qualitative findings during Phase 3. Quantitative analyses were conducted in R (V. 4.4.2). Descriptive and comparative analyses were undertaken on survey and programme activity data to identify patterns that could support or challenge the emerging programme theory rather than to establish causal effects. Analysis of the NoMAD questionnaire data treated Likert-scale responses as ordinal. Construct-level scores were summarised using means, standard deviations, and skewness to describe the central tendency and distribution of responses across sites and time points. Relationships between constructs (e.g. managerial support and shared understanding) were explored using Spearman's rank correlation coefficients. Comparisons between sites or subgroups were examined descriptively through site-level means.

Programme activity data, including the number of scans performed, scan distribution across staff, and timing relative to events or expert visits, were analysed using a combination of descriptive statistics and comparative tests. Median and interquartile ranges were reported for non-normally distributed data. Differences in scanning frequency across contextual conditions (e.g. expert visit days vs non-visit days, event days vs regular days) were assessed using Fisher's exact tests or odds ratios with 95% confidence intervals. Inequality in scan distribution across staff was summarised using the Gini coefficient, which quantifies how evenly scanning activity was shared among trained staff, with lower values indicating more even distribution and higher values greater concentration of scanning among fewer individuals.

Qualitative and quantitative data were iteratively integrated to develop and refine the programme theory throughout. Qualitative data were largely used to develop and refine CMOCs by explaining specific contexts and why participants did or did not respond in particular ways within these conditions, while quantitative data were mainly used to confirm the outcomes, such as the frequency and distribution of scans across staff and over time. Although formal analyses of programme activity data were undertaken only in Phase 3, I reviewed these quantitative data weekly during all phases to identify emerging patterns in scanning activity as a proxy indicator of embedding success. These informal observations informed preliminary interpretations of earlier phases. Formal triangulation of qualitative and quantitative findings occurred in Phase 3, once statistical analyses had been completed.

Echoing Mirzoev et al.[248], I found that some degree of 'toggling' between different levels of abstraction was necessary throughout the analysis. I paid particular attention to these 'ascents and descents' in abstraction, noting them in my reflexive journalling, to support the eventual articulation of the final programme theory at a middle-range level.

Table 6.5 illustrates this multi-phase data analysis through an example of CMOC refinement, showing how qualitative and quantitative data were articulated as explanatory statements using the CMOC heuristic and then progressively refined.

Table 6.5: Example of CMOC refinement through iterative analysis

Phase	CMOC iteration	Illustrative evidence	Analytical notes on inferences
Provisional CMOC	IPT5: If there are colleagues who are also trained in the programme elements (C), direct access to trusted support (M), may allow issues with image acquisition (software, hardware, performing the scan) to be overcome in a timely manner (O).	Based on NASSS framework[192], psychological safety theory[226], learnings from other RHD programmes in the same setting[227], and three expert discussions.	Originally, a more operationally focused, provisional theory.
Phase 1 analysis	P1.6: When a **FNCHW** has a **scanning 'buddy'** (C), they are **less hesitant to scan** (O), because of the **psychological safety** of having another trusted colleague scanning (M).	"[FNCHW3] loves 'sticky stamping' with [Nurse3], so when [Nurse3] is here, [FNCHW3] has far more confidence so it's an example of having confidence when you've got the right buddy with you" [CM3]. "I've got [GP5] to relate to... we've got two sets of eyes... we can both learn off one another... it's useful when you get stuck" [FNCHW5]. "When the doctor is not here and it's just me and FNCHW2(2), we kind of get lost in doing it really properly with the science so we do it when the doctor is here to guide us" [FNCHW2].	I realised that this relationship involved more than nominal support, it reflected a trusted professional bond, hence the idea of a 'buddy'. I drew more explicitly on psychological safety theory from the IPT stage and noted that this seemed specific to FNCHWs, where having a buddy reduced hesitation to scan. I also developed a hunch that the buddy likely needed to be someone with more authority within the workplace hierarchy.

Table 6.5 – continued from previous page

Phase	CMOC iteration	Illustrative evidence	Analytical notes on inferences
Phase 2 analysis	P2.23: When FNCHWs have a **trained colleague to scan with or call on if needed** (C), they're **more likely to scan** (O), because having a scanning 'buddy' makes them **feel supported** (M).	"You know FNCHW3 and I can go out in in pairs, partner and go out [to scan]" [2N3]. "It's nice just giving little bits of feedback to each other" [2GP5]. "But it's just me, so I don't, you know, I don't really have anyone to bounce off" [2FGN5]. "FNCHW5 is really good on the scanner but they often get me, we do our scans together" (2FGGP5).	I realised that this was specifically about having another person who also scans. I returned to 'feeling supported' as the mechanism, consistent with the IPT, recognising that simplicity strengthens coherence in realist analysis[249]. Absences of these conditions also helped clarify the mechanism, and hearing perspectives from multiple cadres and sites was central to refining this insight.
Phase 3 analysis and final CMOC	CMOC3: When FNCHW scanners have **a nurse or GP scanner buddy to scan with (or call on if needed)** (C), they are more likely to scan (O), because they feel supported (M).	Quantitative triangulation showed that four FNCHWs with GP or nurse buddy pairs completed a median of 20.5 scans (IQR: 18.8–23.5), compared to a median of 9 scans (IQR: 3.0–12.5) among FNCHWs without such buddies. This pattern did not hold for FNCHW–FNCHW pairs.	This supported my earlier hunch that the buddy's position in the professional hierarchy mattered, with support from a different cadre facilitating scanning. It also triangulated the pattern that scanners with such support were more likely to scan. While not causal, this basic statistical analysis strengthened my confidence in the inferences I had drawn.

References prefixed with 'FG' denote focus group data and '2' denotes data collected in Phase 2.

Sense-checking process

The final programme theory was sense-checked with stakeholders between September and December 2025. This included members of the NEARER SCAN implementation team who reviewed selected final-draft CMOCs and components of the narrative programme theory that aligned with their areas of expertise or involvement in the programme. In addition, feedback from local implementers was obtained through two main approaches. First, site visits conducted by the

NEARER SCAN principal investigators enabled pragmatic discussions guided by a structured reflection site engagement brochure that I developed in collaboration with Alice Mitchell and research assistant Raelene Collins, with support from the Indigenous Advisory Group (Appendix E.6). These discussions were used to assess the relevance and accuracy of the findings. Second, a one-page summary of the programme theory was distributed to representatives from each cadre and implementation site, inviting targeted feedback via email or, in some cases, online meetings (Appendix E.7). Additional sense-checking occurred through discussions with my supervisory team and other realist researchers within the Health Systems Collaborative research group including Claire Blacklock, Katherine Kalaris, Vira Ameli, Yingxi Zhao, and Helene-Mari Van Der Westhuizen.

Data collection, analysis, and programme theory refinement concluded at the end of Phase 3, when the programme theory was judged by the study team to be sufficiently refined to address the study questions and the planned study period was nearing completion.

6.6 Results

6.6.1 Final CMOCs

The final programme theory is supported by 37 CMOCs, categorised into 10 practical, rhetorical, and sequential questions (Table 6.6). Further details on these CMOCs, their supporting evidence, and their evolution throughout the evaluation are provided in Appendix E.8.

Table 6.6: CMOCs informing the final programme theory

ID	CMOC
1.	**How are scanners selected and trained?**
1	When multiple staff are trained as scanners and visibly scanning (C), it may be considered normal work within the clinic (O), because seeing multiple colleagues scan makes it a shared expectation (M).
2	When staff with authority (e.g. GP or senior nurse), time capacity, and a genuine interest in scanning, are trained as scanners (C), they become personally invested in the programme (M), and advocate for changes to clinic processes that support scanning (O).
3	When FNCHW scanners have a nurse or GP scanner buddy to scan with (or call on if needed) (C), they are more likely to scan (O), because they feel supported (M).
2.	**How are scanners' skills maintained over time?**
4	When cardiac sonographers visit a site for ongoing support (C), scanners are more likely to scan (O), because expert presence makes them feel confident (M1) and that scanning is acceptable to prioritise (M2).
5	When scanners have had few opportunities to practice (C), they are less likely to scan without a visiting sonographer present (O), because skill decline over time reduces their confidence (M).
6	When supervision for FNCHW scanners is delivered off-site and remote supervision via any mode of communication is not a usual practice (C), engagement is limited (O), because FNCHWs see it as optional and deprioritise it in favour of more immediate tasks (M).
7	When scanners seek remote support and receive prompt advice (C), it reinforces the clinical value of the programme (M), which increases their willingness to scan (O).
3.	**How do event-based screening activities help?**
8	When FNCHW and nurse scanners have dedicated time set aside for scanning (e.g. screening events) (C), more scans are done (O), because this protected time within their workflow allows them to prioritise it (M).
9	When FNCHWs can scan children who are already gathered (e.g. at schools or youth programmes) (C), more scans are done (O), because with the logistical responsibility removed, scanning feels like a manageable task (M).
4.	**How do clinic managers influence scanning activity?**
10	When a clinic has a consistent manager and time to build a working relationship with the external programme team (C), the relationship fosters a sense of shared commitment (M1) and accountability (M2), which drives the manager to make practical changes to support scanning (O).
11	When clinics experience high manager turnover and new managers face competing demands without clear guidance or working relationships with the external programme team (C), the resulting ambiguity (M), means manager support for scanning tends to remain nominal (O).
12	When clinic managers mention the programme in staff team communications (e.g. morning team meetings, celebrating scanning efforts) (C), FNCHW scanners are more likely to prioritise scanning (O), because it signals that scanning is a legitimate clinic activity (M).
13	When clinic managers emphasise the benefits of scanning for the community (C), it resonates with FNCHWs' commitment to caring for the community (M), which makes them more willing to participate in scanning (O).

Table 6.6 – continued from previous page

ID	CMOC
14	When clinic managers regularly check-in with scanners about their scanning (C), it signals that scanning is important amid competing demands (M), which reinforces that scanning is legitimate to prioritise (O).
5. How does material and device readiness affect scanning?	
15	When the practical tasks needed to keep scanning operational (e.g. charging, locating the device) are both accessible to and expected of all scanners (C), it signals that scanning is a shared responsibility (M), making scanning activity more likely to be evenly distributed across trained staff (O).
16	When devices aren't ready for immediate use because the operational tasks (e.g. charging) have not been done (C), scanners may abandon their intention to scan (O), because of the frustration that arises when the the expectation of scanning as a ready-to-go task is undermined (M).
6. How is scanning connected to existing workflows?	
17	When other clinic staff, especially GPs, refer patients to FNCHW or nurse scanners for a scan (C), it acts as a social nudge that legitimises (M) the prioritisation of scanning (O).
18	When scanning is visible to other clinic staff (e.g. scanning events) and is explicitly supported by line managers (C), other clinic staff are more likely to refer patients for scans (O), because scanning is collectively seen as an expected clinic activity (M).
19	When FNCHWs' workflows are dominated by delegated or key performance indicator-linked tasks and there are no clear social or formal expectations to scan (C), it is hard to prioritise (O), because it feels optional (M).
20	When scanners have authority within the clinic hierarchy (e.g. GPs) they are trusted to manage their own workflow (C), and are therefore more likely to be able to prioritise opportunistic scanning (O), because this autonomy gives them the confidence to decide when scanning is appropriate (M).
21	When there is a recall system for scanning that is visible to all staff (C), opportunistic scanning becomes easier to prioritise (O), because the recall provides visual prompts for action (M1) and make scanning feel legitimate (M2).
7. How do scanners decide when to offer a scan?	
22	When children present unwell for reasons other than suspected ARF/RHD (C), FNCHW and nurse scanners often choose not to offer scanning (O), because offering an optional check feels inappropriate when there are acute care needs (M).
23	When scanning is offered during a quick visit for a specific reason (e.g. bicillin) (C), participants seem less likely to agree (O), because they want to limit time in the clinic (M).
24	When children become restless during a long appointment (C), scanners are less likely to offer a scan (O), because they want to finish core clinical tasks while the child is still engaged (M).
25	When FNCHWs work in their own community and encounter eligible scanning participants where a cultural protocol prohibits interaction (C), they choose not to scan them (O), because they feel responsible for upholding cultural norms to maintain respect (M).

Table 6.6 – continued from previous page

ID	CMOC
26	When FNCHW scanners work in their own community and carry substantial emotional and family/community responsibilities (C), cumulative fatigue reduces their mental and physical bandwidth (M), which may leads them to deprioritise non-urgent tasks like scanning (O).
8. How is consent approached?	
27	When GP scanners offer opportunistic scans in a busy clinic environment (C), the consent process may be quicker and involve less patient education (O), because GPs consider brief information sufficient for consent at the screening stage (M1), and patients may be more likely to agree (M2).
28	When FNCHW scanners offer opportunistic scans in a busy clinic environment (C), the consent process may take longer and involve more patient education (O), because FNCHWs see it as their role to explain RHD and scanning in a relatable way (M1), and patients may feel more comfortable asking questions in the absence of language and cultural barriers (M2).
29	When FNCHW or nurse scanners have the opportunity to scan in schools but feel unsure about the consent process (C), they may choose not to scan (O), because they are concerned about doing the wrong thing (M).
9. How are images uploaded during technical issues?	
30	When image upload issues (e.g. internet connectivity or upload app errors) are frequent and unresolved (C), scanners may stop scanning (O), because they anticipate the effort won't deliver clinical value (M).
31	When image upload issues (e.g. internet connectivity or upload app errors) are frequent and unresolved (C), scanners may delay uploading (O), because repeated failures make delayed uploading an accepted norm, even if scanners know it's not best practice (M).
32	When upload issues persist despite local attempts to troubleshoot (e.g. home WiFi or mobile hotspot), even when remote support is accessible (C), scanners usually wait for a sonographer visit (O), because remote troubleshooting feels like an added burden in an already busy workflow (M).
33	When FNCHW and nurse scanners don't receive clear confirmation that scans have uploaded and will be reviewed by experts (C), they may start doubting whether the process will improve care (M), so they could stop scanning (O).
10. How does the image review process influence practice?	
34	When reviewers have less experience with RHD or handheld image interpretation and have borderline cases without clinical context (C), they may feel uncertain about some interpretations (M), so they may seek second opinions before reporting (O).
35	When busy cardiologists receive timely notifications that scans have been uploaded for review (C), they are more likely to review the images within the desired timeframe (O), because the reminder brings the task to their attention effortlessly, without them needing to remember to check the portal amid competing priorities (M).
36	When cardiologists are placed on a review roster (C), they are more likely to review the images within the desired timeframe (O), because the roster clarifies who is accountable for reviews during that period (M).
37	When the reviewing system depends on cardiologists volunteering their time and they encounter friction in the process (e.g. clunky software, extra microtasks, or miscommunications) (C), they may disengage from the programme (O), because the optional, unpaid work becomes more burdensome than anticipated (M).

In the next section, I present a narrative version of the final programme theory, which draws on the first 33 of the 37 CMOCs developed through analysis. At the end of this narrative, I include Box 6.1, which summarises the remaining four CMOCs concerning the work of expert reviewers. These CMOCs are included because, although adjacent to the core programme theory which focused on FNCHWs, the task-sharing arrangement with remote expert interpretation remains an important aspect of the planned screening programme in Australia and is likely to be a component of future FNCHW-led ultrasound programmes for other clinical purposes. In addition, limitations in the functioning of this review process could hinder the embedding of echocardiographic screening within FNCHWs' everyday practice.

6.6.2 Final programme theory

This final programme theory explains how, why, for whom, to what extent, and in what circumstances the use of echocardiographic screening for the early detection of RHD could be embedded into the routine work of FNCHWs in remote Australia.

Introducing new practices in these settings is constrained by structural factors, including workforce shortages, high staff turnover (148% of remote nurses annually), and resourcing levels that are insufficient relative to the disease burden[204]. Within these constraints, FNCHWs must manage demanding workloads with clinical, logistical, and cultural responsibilities[84]. As a result, they have limited scope to take on new practices. Nevertheless, my findings show that some FNCHWs are able, in certain circumstances, to incorporate echocardiographic screening for the detection of RHD into their work.

The narrative account of the programme theory explains the mechanisms and contextual conditions shaping this embedding process.

Scope and boundaries of the programme theory

Before turning to this account, the scope and boundaries of the final programme theory are outlined to clarify its focus and the refinements that emerged as understanding of the programme developed throughout the evaluation.

Boundary 1: Introduction of a screening technology in a new setting

This programme can be understood as belonging to the broader family of initiatives that introduce screening technologies into new facilities. Although it initially appeared aligned with task-sharing programmes, given its model of local image acquisition and remote expert review, it lacked the redistribution dynamics that define such initiatives. Both the practice of scanning and the role of the scanner were entirely *new* within these facilities. I therefore propose it is best characterised as a programme introducing a new *screening technology* into a new setting, emphasising its patient-facing nature, and diagnostic purpose, albeit without an interpretation component.

Boundary 2: First Nations community health workers

The theory also focuses on the FNCHW scanners. While other cadres were trained, FNCHWs are positioned at the centre of this programme theory for three reasons. First, they embody the programme's core principle of building local capacity by training community members. This responds directly to community members' perspectives that healthcare should be delivered in culturally appropriate ways, using local languages, and that FNCHWs are best placed to provide this care. Second, they are the cadre being prioritised in the national RHD screening programme, making their experiences particularly relevant to future implementation[206]. Third, distinct features of the FNCHW role shape the workability of new practices and are under-theorised in existing literature compared to other cadres.

FNCHWs occupy a unique and often undervalued position within the health workforce. Although their knowledge and experience are widely recognised at the community level, their formal authority remains limited. As an illustrative example of this, in one Australian jurisdiction, FNCHWs were only recently reclassified out of the same employment stream as cleaning staff, highlighting their structural undervaluation[250]. They also face a persistent lack of role clarity, stemming from substantial variation in job titles and scopes of practice across jurisdictions[250]. Finally, within many facilities, FNCHWs are the primary, or sometimes sole, cultural brokers, often being the only staff members who speak the local language or share cultural ties with patients. This responsibility frequently dominates their workload, as other staff depend on them in ad hoc and uncoordinated ways, with limited acknowledgement of this burden.

Boundary 3: Remote Australian setting

Third, I delineate the boundary of this programme theory to healthcare facilities in remote Australia. In these settings the previously mentioned structural constraints shape how new practices are prioritised, supported, and sustained. Topp et al.[84] found that the degree of remoteness influenced both the scope of FNCHWs' roles and therefore the composition of their daily tasks.

Boundary 4: 'Embedding phase' of normalisation

Finally, I conceptualise embedding as a distinct phase within the broader process of normalisation through which new practices become and remain part of everyday work. This conceptualisation (Figure 6.3) draws on May and Finch's[138] Normalisation Process Theory, integrates Centola's[251] notion of a tipping point, and is informed by the understanding I developed during this evaluation.

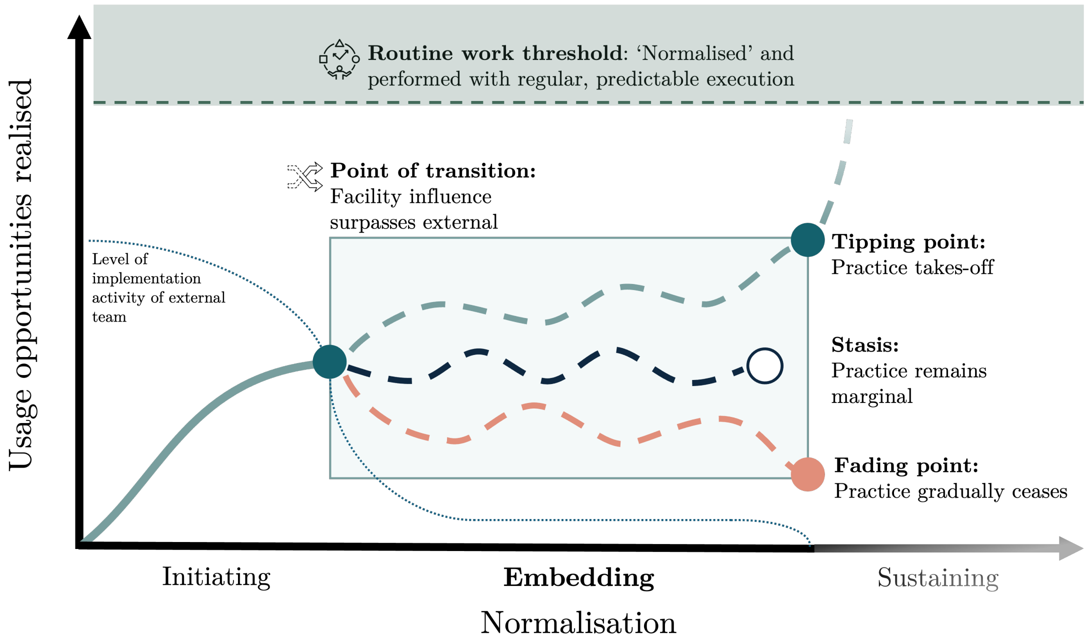

Figure 6.3: Conceptual model of the embedding phase of normalisation. The figure depicts the embedding phase of normalisation, where implementation efforts remain in place but local facility influence begins to surpass that of the external study team. From the embedding period there are three possible outcomes that may follow: a tipping point exit (practice takes off and crosses the routine work threshold), stasis (practice remains marginal in the embedding phase), or a fading point exit (practice gradually ceases). The wave-like lines during embedding illustrate the fluctuating and uncertain nature of this phase. The initiating phase, is characterised by externally led, high-energy implementation work but lies outside the focus of this theory. The sustaining phase represents the maintenance of a fully normalised practice. Here external implementation support is no longer required because facility-level structures sustain practice. It is shown in faded text to reflect uncertainty, as it was not observed within the study period.

I define embedding as the incremental changes made by facility staff to make new practices meaningful and workable within busy local routines and competing priorities[138]. I delineate the embedding phase as beginning when the facility staff team's influence on normalising the practice outweighs that of the external team, though external implementation efforts continue. This phase is characterised by a state of flux, where the new practice is performed inconsistently, and there is a sense of uncertainty and 'fumbling along'. I focused on this embedding phase because it was where facilities diverged the most in their trajectories, making it the richest for explanation. It is in this phase that the majority of my 37 CMOCs are positioned.

I conceptualise three distinct outcomes of the embedding period. These are facility-specific, reflecting how the extent of normalisation is shaped locally rather than at the programmatic level.

I. A tipping point is reached when a critical mass of staff within the facility perceives the practice as 'normal', prompting a shift towards more consistent and accelerated uptake. Centola et al.[251], through experimental studies, estimate this threshold at approximately 25%. Following this inflection, the practice rapidly moves towards becoming routine, where the practice is no longer seen as novel but is considered 'just what we do here', defined by a regular, predictable execution of the work. Suchman's[252] notion of *cognitive legitimacy* is achieved here and the practice becomes taken-for-granted.

II. Stasis occurs when the practice remains marginal within the facility and continues to be performed irregularly. There is a lower level of external team influence through supportive implementation work. This was the most common pathway observed within this evaluation during the study period.

III. A fading point occurs when external implementation support is reduced, for example as funding concludes, before the practice has become sufficiently embedded into routine work.

Preceding the embedding phase is the initiation phase, characterised by purposeful, high-energy implementation activities typically led by an external team (for example, a research team). Also referred to as the 'active dissemination' phase[232], it marks a period of intentional effort to introduce a new practice. In this evaluation, the programme was well-supported from the outset, with clinical credibility, community endorsement, and alignment with regional priorities, and thus meeting many of the conditions commonly associated with successful initiation. The analysis therefore focused on what follows after a programme has been designed and endorsed by local stakeholders, and established within a facility. This also then has the potential to contribute to theory-building in First Nations health more broadly by exploring how even well-executed early implementation efforts represent only the first step in normalising a new practice. The sustaining phase, which follows embedding, involves the ongoing work required to maintain a fully routinised practice. It was not observed during the study period.

Introduction to the programme theory

I use two parsimonious, overarching concepts that emerged from the analysis to structure the programme theory. The first is the extent of *legitimacy* surrounding the new role and how that in turn influences scanning. The second is the *invisible work* surrounding scanning and the support for this work (Figure 6.4).

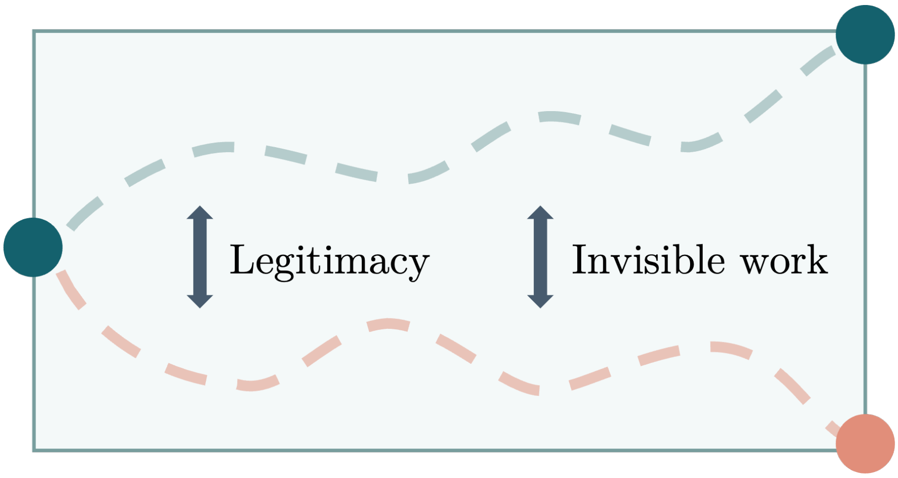

Figure 6.4: Influence of legitimacy and invisible work on embedding. Legitimacy and invisible work act as dynamic forces shaping a new programme's trajectory during embedding: either towards a tipping point or towards fading. When legitimacy is established, it supports embedding; when absent, it constrains it. Similarly, invisible work enables embedding when manageable, but excessive invisible work can impede progress.

Legitimacy

Legitimacy is 'a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions'[252]. It has long been recognised as fundamental to understanding social life[253]. More recently, legitimacy has been positioned as important within the implementation process[138].

Drawing on Suchman's seminal work[252], I make two assumptions about legitimacy that are relevant to this programme theory. First, legitimacy can be strategically shaped through deliberate action. Second, legitimacy does not require complete or unanimous agreement and it can withstand occasional failures in practice or individual dissent, so long as a broader pattern of legitimacy within the group is maintained.

This theory proposes that, as echocardiographic screening is embedded into FNCHWs' work, legitimacy is communicated through three modes, *verbal*, *social*, and *written* (Figure 6.5). *Verbal communication* involves spoken endorsement. *Social communication* refers to implicit cues conveyed through collective behaviour and interpersonal dynamics. *Written communication* involves codification through documents, systems, or other textual artefacts within the facility. Together, these modes shape perceptions of legitimacy during the embedding phase.

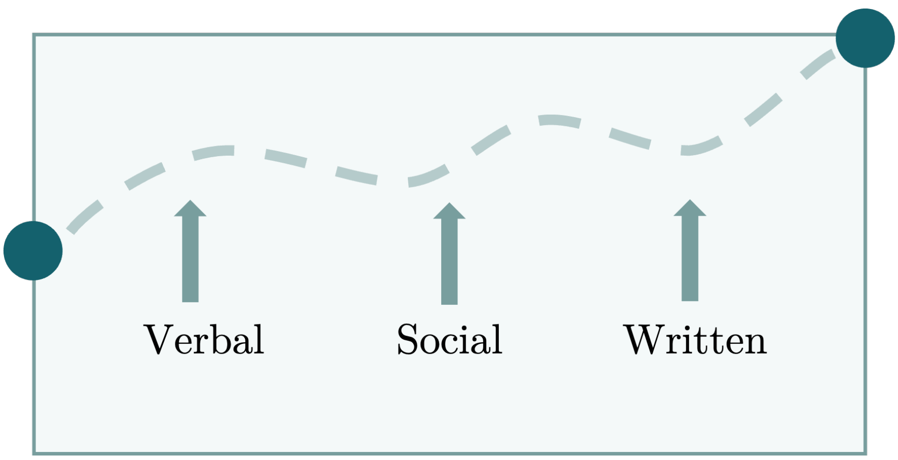

Figure 6.5: Communicating legitimacy in embedding a programme.

Verbal communication

First, legitimacy can be communicated verbally through team communications, individual follow-ups, and from patient referrals within the staff team (Figure 6.6).

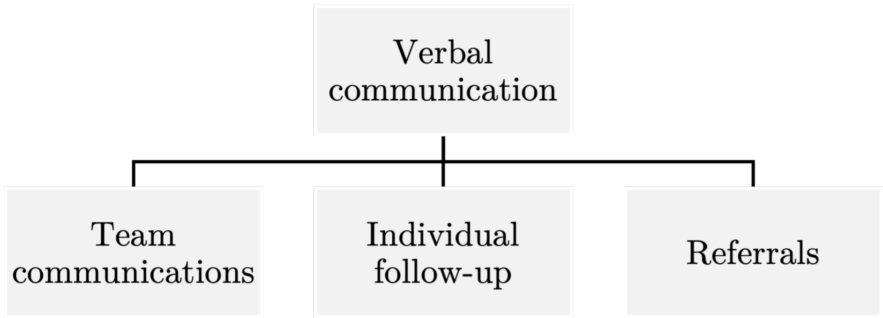

Figure 6.6: Verbal communication of legitimacy

Managers can be a key source of verbal legitimacy. When managers mention a new programme in whole-of-staff communications, as was seen frequently at Site 3 'morning huddles', the act of acknowledgement, even without explicit endorsement, signals its importance and shapes team perceptions of what is acceptable practice (CMOC 12). A similar process occurs more directly when managers follow-up with staff who are trained, for example, by asking them how their scanning is going as was demonstrated by the Site 2 clinic manger, as this personal recognition shows the practice is valued (CMOC 14). Both of these circumstances make it easier for scanners to justify prioritising the new scanner role alongside competing demands. When communication goes further and endorses the health benefits of the programme for the local community, it resonates with FNCHWs' professional values and strengthens their willingness to use it (CMOC 13). Support can be fragile in the event of manager turnover. In these circumstances, a new manager may express support in principle yet, without clear guidance during handover on how to assist, their support may remain nominal and not extend to actively communicating legitimacy (CMOC 11). Site 4, where scanning activity was lowest, experienced particularly high manager turnover.

As a form of verbal communication, legitimacy can also be conveyed by staff other than the manager. When staff suggest that patients see a FNCHW for a scan, this referral itself signals that the new practice is accepted within the facility (CMOC 17). This is particularly strong when the referral comes from staff with authority in the facility, such as GPs, because their referral holds greater weight in shaping what other staff see as acceptable practice. Referrals are themselves more likely to occur when the new practice is visible to other staff and explicitly supported by line managers (CMOC 18).

Social communication

Second, legitimacy can also be socially communicated when multiple trained staff use the new technology, experts make visible visits, and protected time is set aside for scanning (Figure 6.7).

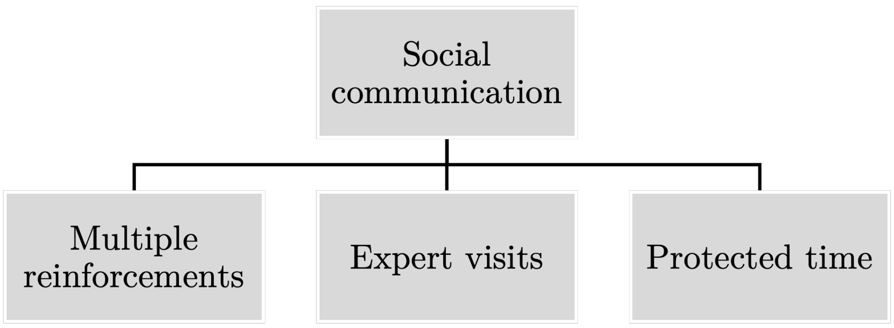

Figure 6.7: Social communication of legitimacy

When multiple staff members use a new technology, the widespread visibility signals to the staff team, especially new staff, that it a shared expectation within the facility, something that cannot be conveyed by an individual alone regardless of their authority (CMOC 1). In this sense there is strength in numbers, illustrating Centola's complex contagions theory[251] that behaviour change requires reinforcement from multiple sources. This was exemplified at Site 3, which had the most scanners complete training. Beyond legitimacy, for FNCHWs, having a clear nurse or GP buddy also trained in the new practice provides support (CMOC 3).

Visiting experts in the technology can also socially communicate legitimacy. Along with building local users' confidence, their presence can help staff justify dedicating time to using the new technology in practice, as colleagues recognise the limited opportunity to access their guidance (CMOC 4). However, when there are not ongoing opportunities to use it after the expert leaves, skill decline can lead staff to become reliant on the expert and only perform the task in their presence (CMOC 5). This dynamic reflects Ebbinghaus's forgetting curve[229]. Without circumstances that create regular opportunities to use a new technology, staff are less likely to practise it, leading to skill decline. Visiting experts can temporarily replenish skills, but without subsequent opportunities for use after they leave, the cycle repeats. Embedding therefore depends not only on training but on creating circumstances that can result in repeated use. This is particularly important in smaller communities, where the limited number of eligible participants reduces opportunities for staff to maintain proficiency.

Allocating protected time for the new practice is a way for managers to socially signal that it is a priority. By setting aside time specifically for the new practice, managers communicate its legitimacy to staff (CMOC 8). Such protected time is especially important for FNCHWs and nurses who may feel unable to prioritise the new practice themselves in their day-to-day work, given their limited autonomy over their workflow. In contrast, scanners with greater authority in the clinic hierarchy, such as GPs, are trusted to manage their own workflow and can more readily prioritise the new practice opportunistically (CMOC 20).

Written communication

Third, legitimacy can be shaped through written forms of communication, often driven by staff with the authority to implement them. These include recall lists of community members requiring a scan and key performance indicators (Figure 6.8).

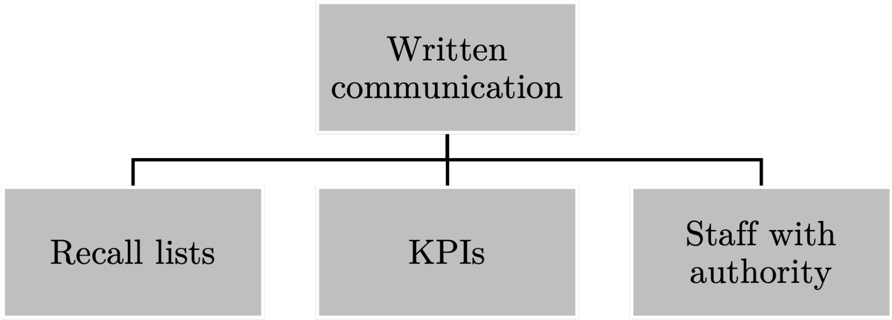

Figure 6.8: Written communication of legitimacy. KPIs = key performance indicators.

Recall lists of patients who need a scan that can be generated through the facility patient record system, as seen at Sites 2 and 5, communicate to both colleagues and patients that scanning is legitimate, while also serving as a visual prompt that makes it easier to prioritise in the moment (CMOC 21). Additionally, because FNCHWs' daily work is closely aligned with key performance indicators, the absence of a measure recognising scanning activity can limit its perceived importance and reduce its likelihood of becoming embedded (CMOC 19).

Implementing these written forms of legitimacy often requires staff with the authority to make service-level changes. When clinical-facing staff with such authority are trained in the new practice and have the capacity to engage, as was the case with the GP scanner at Site 5, the personal investment that is generated from being trained can motivate them to make these changes (CMOC 2). Similarly, when managers remain in their role long enough to build a working relationship with the external team supporting implementation, a sense of shared commitment and accountability can motivate them to implement these more substantial changes (CMOC 10). This function would need to be continued by a dedicated team within the health system after the research team transitions out of its external implementation role.

Temporality of communicating legitimacy

Finally on legitimacy, this evaluation offers preliminary, more tentative insights into the temporal dynamics of these three forms of legitimacy-building communication (Figure 6.9).

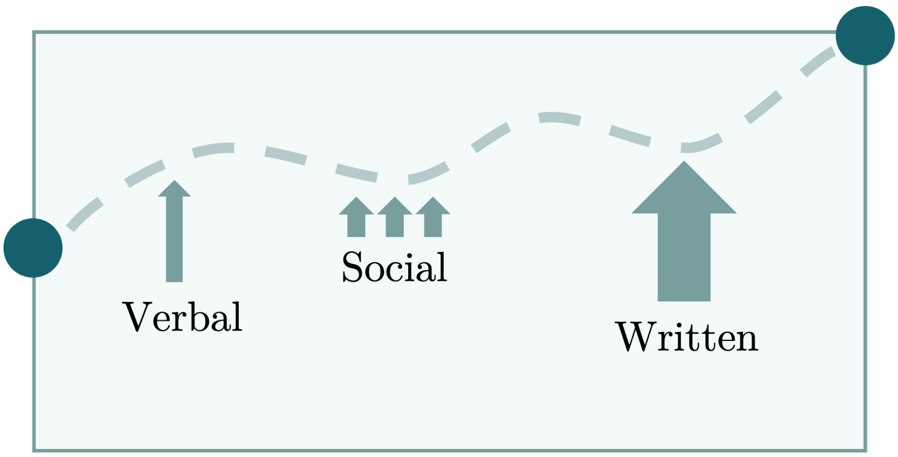

Figure 6.9: A proposed order and hypothesised strength of each form of legitimacy communication. Verbal communication is the most immediate but can be easily overlooked. Social communication is subtle. Written communication offers the strongest and most stable form, though it is slower and more resource-intensive to establish.

Verbal communication appears the most straightforward to implement in everyday practice, as it draws on existing channels such as meetings and conversations. However, it can be easily overlooked in busy environments where competing priorities limit opportunities for discussion. Social communication seems to operate more subtly, reinforcing legitimacy through shared behaviours and relational cues among colleagues. Its strength lies in collective visibility and peer reinforcement, yet it may be vulnerable to disruption when staff turnover or shifting team dynamics alter these informal networks.

Written communication may offer the strongest and most stable form of legitimacy, particularly in settings with high staff turnover. Once formalised, legitimacy appears to carry a stronger mandate and be less dependent on individual champions, allowing it to persist even where there is staff turnover. However, written forms also seem the most resource-intensive and slowest to establish, often requiring time, coordination, and higher levels of institutional or health system-level support. Written communication is most influential where such documentation is already treated as legitimate within the system. In the study settings, key performance indicators, as a written form, shaped workforce behaviour. By contrast, where the formal documents carry little practical weight, written legitimacy can remain nominal and fail to translate into everyday practice.

Invisible work

Invisible work refers to activities that, despite being essential to the embedding of a programme, are often under-recognised and undervalued[254] (Figure 6.10). The concept of *invisible work* was first introduced by Daniels[255] to describe women's unpaid labour, drawing attention to how essential tasks can be systematically overlooked. Subsequent scholarship has shown that such work is typically disproportionately shouldered by lower-status workers. In this study, invisible work was also undertaken by other cadres, particularly facility managers, whose behind-the-scenes coordination and support were important in shaping both the legitimacy of the scanner role and the invisible work undertaken by FNCHWs, although this was not the primary focus of this programme theory. In sociotechnical studies, scholars have highlighted how the implementation and everyday use of technologies are underpinned by extensive invisible work[256].

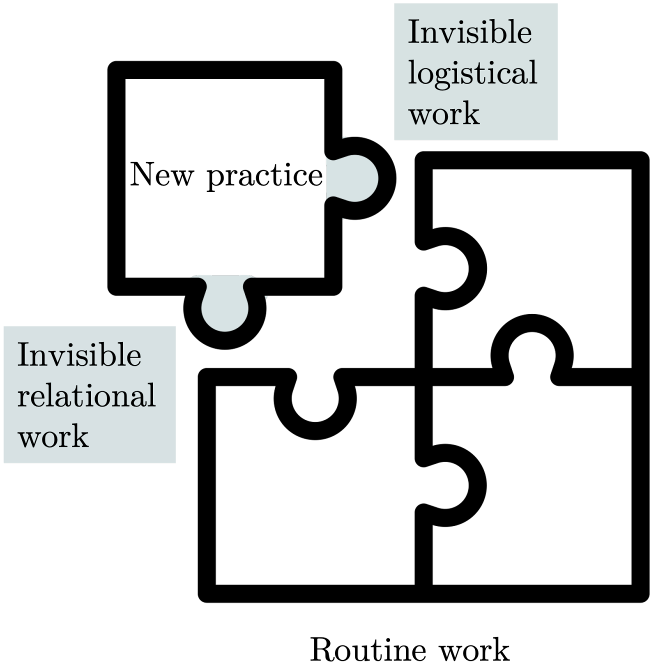

Figure 6.10: Invisible work is inherently part of embedding a practice into routine work

Drawing on Star and Strauss[254], Timmermans and Berg[257], and Allen[256], I work with three underlying assumptions about invisible work that are relevant for this programme theory. First, invisible work is often created or redistributed through the introduction of new technologies. Second, it is cumulative in nature and can become burdensome over time without ever being formally recognised. Third, efforts to make invisible work visible may have unintended consequences, such as increased surveillance, bureaucratisation, or a loss of autonomy.

This theory argues that there are two forms of invisible work that shape the embedding process for echocardiographic screening by FNCHWs: logistical work and relational work.

Logistical work

Embedding echocardiographic screening into routine practice generates invisible logistical work. By this I mean the tasks required to make the technology usable in everyday practice, such as finding participants, or locating, charging, and maintaining devices, uploading scans, and troubleshooting technical issues.

How responsibility for this logistical work is distributed can either support or hinder embedding. FNCHWs often shoulder a disproportionate share of these tasks which can reduce their capacity to use the new technology they have been trained in. When these burdens are temporarily removed, such as during screening events where children are already gathered for scanning and devices are pre-charged in anticipation, screening shifts from feeling unmanageable to feeling doable, as the task becomes less disruptive to other responsibilities, making scanning more likely (CMOC 9). Embedding is also strengthened when the operational tasks needed to keep the technology running, such as charging or locating devices, are accessible to, and an expectation of all trained staff. This signals that use of the technology is a shared responsibility and encourages scanning to be taken up more evenly across the trained staff (CMOC 15). Despite having only two scanners, this was the case at Site 2, where neither task posed problems. By contrast, when these tasks fall to a single staff member seen as most capable, as at Site 4, responsibility became concentrated and widespread use became vulnerable to disruption, for example, when that staff member left the facility.

Logistical work can undermine staff expectations of a new practice. When this work is not done, using echocardiographic screening feels harder than anticipated, creating frustration and prompting abandonment of intentions to use it (CMOC 16). Logistical work can also create a gap between the expected value of echocardiographic screening and the realities of its use. When essential processes are not performed, or it is unclear if they have been performed or not, staff lose confidence that their efforts will deliver clinical benefit. This undermines the sense that the new practice is meaningful, eroding the practice's perceived worth and leading to disengagement or discontinuation (CMOCs 30, 33). In contrast when this invisible work is efficient it can reinforce clinical value (CMOC 7).

Ongoing invisible work from technological issues shapes how staff engage with a new practice over time. When these problems continue, staff may adapt by normalising workarounds or delays, as repeated failures recalibrate what is accepted, even when this deviates from best practice (CMOC 31). In addition, remote support arrangements can generate invisible work that limits engagement. When remote supervision is introduced in settings where it is not standard practice, for example where FNCHWs are used to resolving issues in person and are not routinely engaged in scheduled, technology-mediated supervision, it is often seen as optional and deprioritised in favour of other tasks (CMOC 6). Similarly, when problems arise, staff often defer action until in-person support is available, because remote troubleshooting adds to already heavy workloads (CMOC 32).

Relational work

Embedding echocardiographic screening also generates invisible relational work. By this I mean the often-overlooked cognitive and interpersonal effort involved in coordinating with colleagues, negotiating roles, and deciding how and when to use the new technology.

Deciding when it is appropriate to use a new point-of-care technology amid competing priorities requires considerable relational judgement. This may involve choosing not to offer the use of the technology in moments that feel clinically inappropriate, for example, during an acute illness (CMOC 22), when a child is becoming restless in a long appointment (CMOC 24), or when a patient is only briefly visiting the facility for another reason (CMOC 23). In these instances, patients may feel more comfortable declining an assessment offered by a community member who they know than an assessment offered by a doctor, whose authority carries different weight[258]. Similarly, staff with lower status in facility hierarchies may refrain from using a new technology when they are unsure about local expectations or procedures, particularly around consent (CMOC 29).

Relational work is particularly demanding for FNCHWs in these settings. Cultural protocols may mean that they cannot use the new technology with certain patients (CMOC 25). The diagnostic function of point-of-care technologies can also place additional emotional demands when used with kin or community members, as recognising illness in someone close can be emotionally difficult. Over time, the accumulation of these relational and emotional demands generates hidden fatigue, and can reduce capacity to prioritise new practices that often require more mental energy (CMOC 26).

Relational work depends on professional role and social positioning, which shape how interactions around a new practice unfold. For example, for GPs the consent process in a busy facility may be brief, as positional authority means limited information is often seen as sufficient and patients are more likely to agree (CMOC 27). By contrast, FNCHWs often provide more extensive explanation, drawing on shared language and cultural proximity, with patients feeling comfortable to ask questions and seek reassurance (CMOC 28). This uneven distribution of relational expectations reflects a classic feature of Lipsky's street-level bureaucracy[139], where frontline workers exercise discretion in ways shaped by their role and social relationships. The result is that the same practice places differing relational demands across cadres.

Invisible work and a new practice

In summary, invisible work cannot be separated from the practice that is being embedded. It is the work that influences whether new practices move from the periphery into the core of routine care. Programme planning often underestimates this burden and overlooks the extent of hidden labour required. Embedding therefore depends on recognising the extent of invisible work and designing strategies to reduce or redistribute it, so that the practice can become part of regular, predictable routines.

The work of the expert reveiwers

As noted at the start of this section, the remaining four CMOCs relate to the work of the expert reviewers and are summarised in Box 6.1.

Box 6.1: Expert review process

Although the programme theory focuses on the embedding of echocardiographic screening within the work of FNCHWs, the functioning of the remote review process is essential to the programme's overall viability. This component currently operates under fragile conditions, as cardiologist participation is voluntary and sits outside their core work responsibilities, making it susceptible to disengagement when technical or practical issues arise, such as clunky software or communication breakdowns (CMOC 37). Reviewing scans also involves substantial cognitive and interpretive effort, particularly for lower-quality or borderline images. Less experienced reviewers may seek second opinions from colleagues in such cases, extending both the review time and the number of steps required (CMOC 34). However, two supports appear to assist the workability of the review process: when clear review rosters are established, they create conditions that clarify accountability (CMOC 36), and when automated notifications of new uploads are in place, they create conditions that prompt timely action and lessen the cognitive load otherwise required to manually check for scans during rostered shifts (CMOC 35).

6.7 Discussion

6.7.1 Summary of findings

This programme theory explains how legitimacy and invisible work shape the embedding of echocardiographic screening into the routine work of FNCHWs in remote Australian health facilities.

First, legitimacy is important to the new FNCHW role of *scanner*. Legitimacy can be signalled verbally, by managers or among staff, socially, through service delivery models and modes of support, and in written form, with integration into existing systems.

Second, echocardiographic screening generates invisible work for FNCHWs that is essential for its workability in practice, but also burdensome, and can affect the consistency of its use. Hidden logistical tasks such as charging devices and troubleshooting issues shape whether echocardiographic screening is used opportunistically. Echocardiographic screening also involves hidden relational work for FNCHWS as they navigate cultural and workplace expectations.

These two concepts appear to have emerged because FNCHWs occupy positions of comparatively low status and limited formal authority within the health workforce. As such, their experience of embedding echocardiographic screening into their routine work differs from that of other cadres. For example, if the programme theory had instead focused on the GP scanners, who hold greater professional authority and autonomy, the concepts shaping embedding would likely be different, with the legitimacy of their roles as scanner less contested and the burden of invisible work likely less pronounced. For FNCHWs, understanding and addressing these two concepts will help create the conditions that enable them to perform scans more regularly, maintain their echocardiographic skills, and ultimately support earlier detection and management of RHD.

6.7.2 Integration with substantive theory

The plausibility of a programme theory is, in part, supported by its analogy with existing knowledge and/or substantive theories[249]. This section shows how the programme theory contributes to scholarship on legitimacy and invisible work in implementation research by advancing propositions that distil its explanatory insights and situate them within the wider literature.

Legitimacy

> I. The emergence of a new role depends on legitimacy, which is a dynamic process, negotiated in practice and continually reassessed during embedding.

Role salience refers to the hierarchy of roles a person holds and shapes expectations and behaviour[259,260]. Its structure depends partly on role clarity, where clear expectations provide a basis for prioritisation[261]. As demonstrated by Topp et. al.[84], FNCHWs generally have low clarity of their roles, with expectations varying substantially between facilities and across different colleagues. My findings extend this understanding by showing that when a new role (i.e. one that sits outside the traditional boundaries of FNCHW work) is introduced, this low role clarity, combined with limited authority, a busy remote healthcare environment, and shifting norms in high-turnover teams, results in limited scope for FNCHWs to actively negotiate the new role. Instead, the role emerges passively, shaped through tacit recognition from colleagues and patients in response to legitimacy (Figure 6.11).

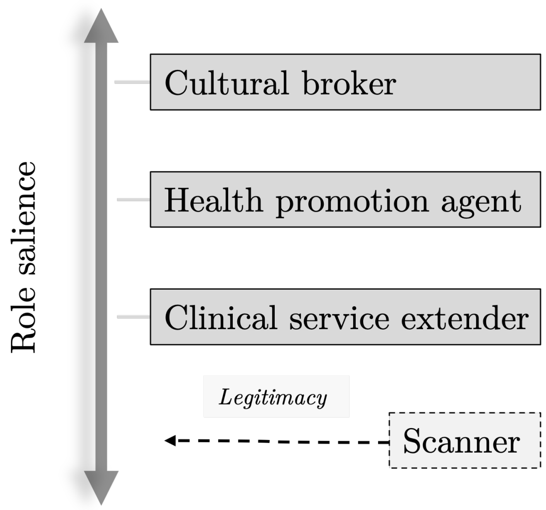

Figure 6.11: Example role salience hierarchy for a FNCHW health worker. Established roles occupy a structured salience ladder which has a low clarity. The emergent role of scanner sits at the periphery and may be drawn inward as legitimacy is conferred, though this process is dynamic (illustrated by the dashed line). Roles adapted from Topp et. al.[84]

Although legitimacy is negotiated moment to moment, the literature on legitimacy stages provides a framework for understanding the sequence of how it may develop over time. Suchman's[252] distinction between pragmatic, moral, and cognitive forms of legitimacy can be applied to new roles for FNCHWs. In their study of emerging industries, Aldrich and Fiol[262] proposed that legitimacy often develops sequentially, beginning with pragmatic legitimacy, moving to moral legitimacy, and, ultimately, reaching the most stable form, cognitive legitimacy. My findings suggest that in facilities with strong normative commitments, such as equity in First Nations health, moral legitimacy may precede pragmatic legitimacy. In such environments, staff may agree upfront that a practice is the right thing to do, but the legitimacy hurdle lies in its workability in practice.

While legitimacy is continually worked out in practice, the ways in which this occurs are shaped by actors' organisational position. In their study of integrating nurse practitioners into the Albertan health system, Reay, Golden-Biddle and Germann[263] showed how legitimacy was actively negotiated through the cultivation of opportunities. Nursing leaders, by drawing on social connections, experience, and system knowledge, were able to recognise and strategically time opportunities to advance the visibility of the role. My findings extend this by suggesting that the negotiation of legitimacy is conditional on actors' positioning within workplace hierarchies. For example, with limited autonomy, FNCHWs could only negotiate legitimacy in structured contexts created by implementation design e.g. at screening events, whereas GPs, trusted to manage their workflow, could do so more fluidly in everyday practice. This suggests that while legitimacy is continually negotiated, the scope for doing so varies according to position.

> II. When the introduction of a new practice necessitates a new role, legitimacy and usage are mutually reinforcing, but whilst embedding, legitimacy exerts a greater influence on usage than the reverse.

Embedding a new practice involves an evolving relationship between usage and legitimacy, in which the balance of influence changes over time. Colyvas and Jonsson[264] similarly contend that diffusion and institutionalisation may be mutually reinforcing. My findings extend this by adding a temporal dimension and specifying the type of programmes to which it applies. In my evaluation scanning appeared to reinforce the legitimacy of the scanner role, and building legitimacy, in turn, seemed to facilitate further scanning. However, during the embedding period, when use was still irregular, these legitimising effects appeared weaker than when scanning was performed with more predictable, regular execution (Figure 6.12). In the embedding phase, 'proof by doing' may therefore be insufficient to establish legitimacy: even enthusiastic early users can falter if their actions are not yet recognised as proper, appropriate, or desirable across the facility. This suggests that, in the early stages, legitimacy for a new role cannot be achieved through usage alone but must be actively cultivated through deliberate actions that signal it as desirable, proper, and appropriate within the facility.

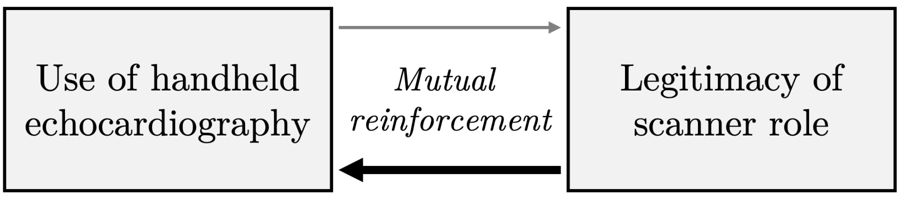

Figure 6.12: Mutual reinforcement between use of handheld echocardiography and the legitimacy of the scanner role. During embedding, irregular use means the effect on legitimacy is less than legitimacy's support of further use.

> III. During the embedding period, legitimacy can be built through verbal, social, or written signals, independent of actual use of the new practice.

Beyond usage, legitimacy can be built through a variety of signals. This proposition was detailed extensively in the narrative summary of the programme theory. Reay, Golden-Biddle and Germann[263] showed how nursing leaders advanced the legitimacy of the nurse practitioner role through written communication, integrating it into job descriptions. My findings similarly showed that written forms can build legitimacy, though the emphasis differed. Whereas their study highlighted an active attempt to formally legitimise a new role, in the NEARER SCAN study, service level changes like recall lists and key performance indicators, were created primarily to increase scanning, with legitimacy reinforced as a secondary effect. These written signals were particularly influential for FNCHWs, whose workflows are generally driven by formal measured tasks (albeit with frequent disruptions to fill cultural brokerage or service gaps).

> IV. Legitimacy should be understood at the collective level, and concern not only value but also fit alongside competing priorities.

This final proposition corroborates Suchman's[252] definition of legitimacy while sharpening emphasis on what this means for evaluation practices. My findings suggest that legitimacy is not a matter of individual assent but the shared perceptions and assumptions of colleagues (Figure 6.13). Moreover, legitimacy cannot be reduced to whether a new practice is seen as valuable; it also depends on whether it is regarded as fitting within existing cultural and organisational norms. In this respect, I am in agreement with Colyvas and Jonsson[264], who caution that legitimacy is too often treated narrowly as what is socially desirable where many practices could appear legitimate on this basis without becoming embedded. For evaluative purposes, this means legitimacy might be assessed in ways that capture both its collective basis and its normative fit, rather than focusing solely on individual perceptions of value.

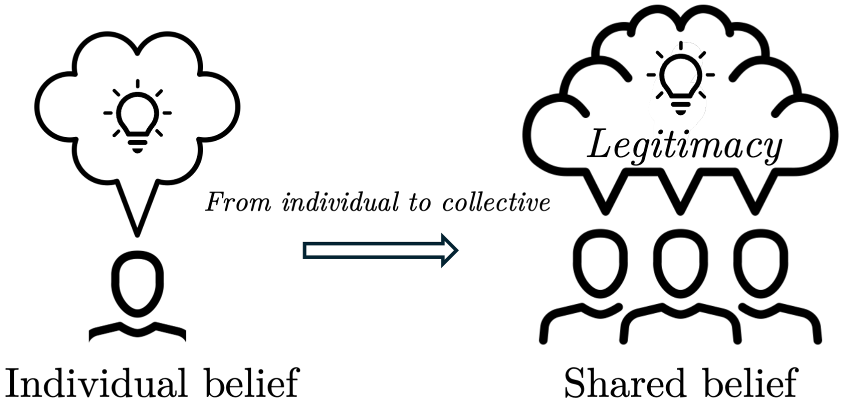

Figure 6.13: Legitimacy as understood at the collective level.

Invisible work

I. When logistical work is shared and predictable it supports embedding; when concentrated and inconsistent it hinders it.

This proposition highlights how the organisation of logistical work shapes the emebedding of new practices. Star and Strauss[254] described invisible work as essential yet often undervalued maintenance labour that sustains systems in practice. My findings extend this by showing that it is not only the presence of logistical work but how it is distributed and coordinated that matters. When this work is shared and routine, it reinforces collective responsibility and supports embedding; when fragmented or inconsistent, it erodes confidence in the technology's reliability and undermines its perceived value.

II. Hidden relational work that is integral to FNCHWs' roles can also make it harder for them to embed new practices into their routine.

This proposition builds on the extensive work of Topp et al.[84,250,265], by illustrating how the nature of FNCHWs' relational work influences the embedding of new practices. My findings suggest that this relational labour can both enable and constrain the embedding of echocardiographic screening into everyday workflows. On one hand, FNCHWs' intimate knowledge of their communities, developed through longstanding relationships of trust, allows them to judge when and where it is appropriate to offer echocardiographic screening. On the other, the relational expectations placed upon them—what a FNCHW participant in Topp, Edelman, and Taylor[265] described as being “everything to everyone”—create a tiring emotional burden. This breadth of responsibility can make it difficult to prioritise new, discretionary or non-routine tasks, such as opportunistic scanning, even when FNCHWs recognise their importance.

6.7.3 Transferability of the programme theory

In this section, I discuss both the transferability and the *specification of ignorance* of the programme theory, that is, where its explanatory power may hold beyond this case, and where its reach is likely to be limited. This involves recognising not only the conditions in which the theory may demonstrate genuine explanatory power, but also the areas of uncertainty and omission that may constrain its wider transferability[244,266].

The concepts of legitimacy and invisible work may hold relevance for other programmes that aim to embed the use of new technologies into the routine work of employees who have limited formal authority within a setting. This may typically be cadres such as community health workers, or, in some facilities, nurses. Rather than a theory about echocardiographic screening itself, it may be understood as a case through which to examine how workers positioned lower in professional hierarchies attempt to embed a practice that is new to both their role and their facility, and the conditions under which such efforts are legitimised and aided or hindered by invisible work.

At the same time, there are several areas where uncertainty remains. First, the relationship between the competence of individual scanners and the embedding of echocardiographic screening into routine work, and how this dynamic evolves over time, remains unclear. The analysis did not assess the temporal or quantifiable thresholds at which competency develops or how quickly competency diminishes without use. I hypothesise that early and sustained opportunities for practice are essential to move toward embedding the practice, yet this likely varies by individual. Second, the influence of system integration, such as the inclusion of scanning in FNCHW training curricula or budgets, could not be fully explored but is likely to interact strongly with legitimacy and potentially even the nature of invisible work. Finally, the trajectories of embedding over time remain uncertain. Most sites in this study were in stasis at the time of writing. It is not yet clear how these trajectories would evolve once external implementation support is fully withdrawn, and whether internally generated legitimacy would be sufficient to continue the practice.

6.7.4 Strengths and limitations of the realist evaluation

Strengths

First, considerable attention was given to ensuring the trustworthiness and plausibility of the analysis. Multiple strategies were used to support rigour, including triangulation across data types, investigator discussion to test interpretations, and deliberate consideration of realist criteria for plausibility, consilience, simplicity, and analogy, when refining programme theories. Second, the multi-site, multi-methods design strengthened explanatory depth and transferability. Analysing five sites with differing conditions and combining qualitative and quantitative data enabled comparison of emerging patterns and a richer understanding of the mechanisms underlying variation in embedding. Third, the longitudinal and embedded nature of the evaluation enhanced validity. Sustained evaluation over two years enabled observation of change over time, while proximity to implementation activities allowed a nuanced understanding of local dynamics that might otherwise have been overlooked by external evaluators.

Limitations

First, data were not collected directly from participants of the screening programme. The evaluation focused on workplace dynamics within the facility rather than on patient experiences. However, some FNCHW accounts indirectly reflected patient preferences regarding timing of scanning and who was comfortable being scanned, which likely influenced embedding and warrants further study. Second, both implementation and evaluation activities naturally emphasised measurable indicators, particularly the number of scans performed. This focus may have led to a subtle privileging of quantity over quality in interpreting the success of embedding, overlooking aspects such as quality of interaction with screened participant. Third, the evaluation was conducted with two overlapping audiences in mind: a practical audience informing future implementation of echocardiographic screening for RHD, and an academic audience, where my concern was for theoretical contribution. Balancing these aims required trade-offs, particularly in deciding the level of abstraction and specificity in the presentation of findings. Fourth, the analysis foregrounded the invisible work of FNCHWs and did not examine in depth the invisible work of the facility managers, whose behind-the-scenes efforts to introduce scanning likely shaped site-level trajectories in the embedding period.

6.8 Conclusion

This chapter has explained how the embedding of echocardiographic screening into the routine work of FNCHWs for the early detection of RHD in remote Australia is largely dependent on two interrelated concepts. First, the legitimacy of FNCHWs enacting the role of 'scanner' and performing scans regularly enough to maintain competency. Second, the invisible work that surrounds this practice, which is essential to its workability yet can simultaneously impede its integration into everyday clinical routines.

7

Discussion and conclusion

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7.1 Chapter preface

In this final chapter, I summarise the key findings of this thesis, discuss their implications, and outline policy recommendations. I then consider the thesis strengths and limitations and reflect on the theory-based evaluation approach. Finally, I identify future research directions and conclude the thesis.

7.2 Summary of key findings

It has been previously established that echocardiographic screening is an evidence-based approach to the early detection of RHD, and has the potential to reduce the disease burden in remote First Nations Australian communities[60,66]. Realising this potential, however, depends on effective implementation so that screening reaches those most likely to benefit. This thesis aimed to improve understanding of how echocardiographic screening can be implemented in these challenging settings.

The findings reported throughout this thesis are cumulative. That is, the findings from the reviews in Chapter 3 helped inform the content and process of implementation design in Chapter 4, which in turn shaped the evaluation reported in Chapters 5 and 6. Accordingly, although the main findings arise from the evaluation chapters, they are underpinned by the prior work.

In Chapter 3, I identified several implementation lessons from diabetic retinopathy screening that may be transferable to RHD screening, particularly around workforce training and community engagement. I also mapped how Theory of Change has been applied in similar child health service programmes, highlighting its variable use and its limitations as a standalone approach to evaluation.

Then in Chapter 4, I co-designed implementation plans for an RHD screening programme with stakeholders from five remote First Nations communities. I defined the programme's core functions and used a Theory of Change approach to guide discussions about locally tailored form, including planned implementation strategies, and how and why the programme was expected to improve RHD outcomes.

Next in Chapter 5, I conducted a process evaluation of the screening programme. I found that the implementation of echocardiographic screening for RHD in remote First Nations communities led to more modest and inconsistent scanning activity than anticipated over the 2.5-year study period. There were substantial gaps in intervention fidelity across key components of the programme: handheld devices were often not accessible or charged, image uploads were frequently unsuccessful, and off-site reviews were generally slower than planned.

Finally in Chapter 6, I built on this with an explanatory account of the implementation through a realist evaluation. Two broad sets of issues appeared to underpin the pattern observed in embedding opportunistic screening into routine for the FNCHWs. First, the uncertain legitimacy of their new 'scanner' role within busy workplaces with high staff turnover; and second, the extent of the invisible work generated by scanning, which meant that the size of the task was greater than initially appreciated.

7.3 Implications of findings

The findings of this thesis have several practical implications for ongoing and future RHD screening efforts. Perhaps most pertinently, they suggest that an opportunistic screening programme, led by FNCHW scanners, is difficult to implement and embed into routine work. This is pertinent as this is the approach currently being explored for scale-up by NACCHO[80]. Event-based screening, however, emerged as an important implementation strategy to support higher screening coverage, albeit at greater cost. This suggests the potential for a hybrid approach, which would involve periodic screening events with visiting sonographer support, alongside ongoing efforts to strengthen the conditions needed for opportunistic screening within facilities between events. The appropriate balance between opportunistic and event-based screening will need to be determined by individual facilities and communities, guided by local priorities and workforce capacity.

The thesis also has implications that may extend beyond RHD screening to other programmes with comparable components delivered in analogous remote First Nations contexts. The explanatory concepts developed in this thesis, particularly legitimacy and invisible work, may be useful for understanding how, why, for whom, and under what circumstances FNCHWs are able to better embed such programmes into routine work.

The importance of legitimacy in embedding has been previously described. In NPT, a theory I return to throughout this thesis, *legitimation* is a key component of the 'cognitive participation' construct[138]. My findings align with NPT's central claim that embedding is collective work. That is, it depends on whether the staff of a facility coordinate around a new practice, rather than on individual intention alone. The contribution here is therefore mainly one of emphasis. In task-sharing programmes delivered by staff in time poor settings with limited authority, legitimacy becomes a particularly useful lens for explaining why some practices become routine and others do not. Consistent with recent work conceptualising legitimacy as a form of social infrastructure in health and technology[267], I add a pragmatic focus on how this infrastructure can be studied in practice. Specifically, I have shown that examining how legitimacy is communicated within a setting, through what is said and by whom (verbal communication), who is visibly involved and what time is made (social communication), and how expectations are expressed in local documents and systems (written communication), may be a useful starting point for assessing legitimacy as social infrastructure.

The concept of invisible work has also been previously discussed, although the existing literature mostly focuses on *logistical* work within socio-technical studies[254]. By contrast, invisible *relational* work is less frequently explored, especially through empirical accounts of the kind provided here. Even so, the full extent of relational work undertaken by FNCHWs in their own communities is unlikely to be captured in this thesis. This would benefit from further investigation led by local researchers, whose nuanced understanding of community dynamics could better examine how relational work shapes FNCHW workflows and their capacity to embed new practices into routine service delivery. These forms of invisible work matter because systems are often drawn towards performance metrics to assess and demonstrate progress, particularly in settings where the scale of need exceeds available resources, as is the case within First Nations healthcare[268]. However, the findings in this thesis caution against measurement without critical consideration. This is aligned with scholars such as Suchman[269] who have argued that a singular focus on metrics can conceal the effort and judgement that underpins good work. This risks a drift away from recognising what actually happens in practice and therefore supporting and resourcing invisible work appropriately.

7.4 Policy recommendations

Drawing on these findings and their implications, I make two policy recommendations that could strengthen the implementation of RHD screening in remote First Nations communities in Australia.

1. Create the conditions necessary for opportunistic screening

Implementation efforts should prioritise the conditions that enable FNCHWs to embed screening into routine clinical work. This includes explicit work to build the *legitimacy* of the FNCHW scanner role within each facility. Legitimacy building should extend beyond the scanners themselves. While training and ongoing support remain essential, deliberate attention is also needed to engage other staff across the facility[140]. Focus should be on what can be done to communicate legitimacy, verbally, socially, and in written form.

Policy should also recognise and support the *invisible work* required to make opportunistic screening feasible. This includes the logistical work of ensuring devices are accessible, charged, maintained, and that image upload and review processes function reliably. It also refers to the relational work required to negotiate time, prioritisation, and role expectations within busy teams. Different cadres may be positioned to undertake different forms of invisible work, and implementation support should be designed with these role differences in mind.

2. Supplement opportunistic screening with periodic event-based screening supported by visiting sonographers

The findings suggest that periodic screening events and in-person sonographer support can increase community screening coverage and strengthen the conditions for opportunistic screening by FNCHWs. Although these strategies have a higher cost, they should be considered as planned supplemental support strategies to opportunistic delivery, particularly given the practical limits observed in relying on off-site support. Screening events can provide predictable opportunities to reach eligible participants, create a positive environment for both scanners and participants, and reinforce scanner confidence and momentum.

7.5 Strengths and limitations of the thesis

Strengths and limitations specific to each work package are discussed within the relevant chapters. Here, I summarise overarching strengths and limitations applicable across the thesis.

Strengths

First, the cumulative nature of this thesis meant that findings were progressively integrated and built upon to enhance rigour, rather than treated as standalone results. Second, the thesis draws on multiple methods to provide a more comprehensive and policy-relevant account of what is required to implement echocardiographic screening. Third, it explicitly acknowledges the complexity of delivering screening in remote First Nations health services, and uses theory-based evaluation approaches to make that complexity more analytically manageable. This was conducive for producing plausible, actionable inferences about how to implement screening.

Limitations

First, this thesis evaluated a programme delivered as part of a trial, albeit with purposefully limited input from the external implementation team to approximate 'real-world' conditions. This nonetheless created slightly artificial conditions for designing and evaluating implementation, because staff were expected to embed a non-urgent task into already crowded workloads, requiring reordering of priorities and role boundaries, without system-level supports such as dedicated funding or backfill. Second, much of the thesis was informed by discussions with local stakeholders, whose engagement was naturally limited by competing responsibilities. As a result, visibility of day-to-day implementation work was uneven, particularly between site visits, and some processes could only be understood intermittently rather than through sustained on-site presence. In addition, as a non-local researcher within a non-local team, my interpretation of some local cultural and relational dynamics shaping implementation was inevitably partial. Third, as my understanding evolved over the thesis, I became more aware of the limits of evaluation in complex health systems. That is, an appreciation for the fact that evaluation work can generate plausible and useful inferences, rather than complete answers or decisive proof. Its contribution is therefore best understood as incremental[270].

7.6 Reflections on theory-based evaluation approaches

Theory-based evaluation approaches, including Theory of Change and realist evaluation, are increasingly used in programme evaluation, and there is a recognised need to better understand how they can be combined in practice[271]. These approaches differ in how they treat causation. Theory of Change is underpinned by a successionist logic in which outcomes are expected to follow a sequence, whereas realist evaluation is informed by generative causation in which outcomes are produced through mechanisms that are triggered (or not) in particular contexts[272]. In Weiss's terms[107], Theory of Change lends itself to articulating *implementation theory*, intended steps and assumptions, while realist evaluation is better suited to developing *programme theory*, explaining how and why outcomes are generated. Despite these differences, many, including Blamey and Mackenzie in their 2007 paper[273], argue that synergy is possible, and that the approaches can be used in complementary ways rather than treated as competing alternatives . However, there have been relatively few empirical examples demonstrating how this can be done in practice[274].

In this thesis, I combined the two approaches in a way that was intended to be both pragmatic and conceptually appropriate[273]. Theory of Change was used to support implementation design and early planning with stakeholders, and to structure fidelity assessment against the intended implementation model. Realist evaluation was used to address explanatory questions about how, why, and for whom opportunistic screening did or did not become embedded, using a generative account of causation[272]. This complementary approach was shaped by time and resource limitations[274]. I found it most feasible to use Theory of Change with stakeholders for shared programme mapping and monitoring, while reserving more detailed generative explanations for my analysis. However, this division required me to move between successionist and generative logics, and to be explicit about which questions each approach was being used to answer and why. As a result, the thesis provides an empirical example of how the approaches can be used synergistically within a single body of work.

Finally, the relationship between trials and theory-based evaluations is contested, particularly within the realist literature. Some propose 'realist RCTs' that specify and test realist hypotheses using experimental methods[275,276], while others question whether this is possible while remaining consistent with a realist logic[277,278]. Despite these differences, there is shared emphasis on making more use of theory in trials. In this thesis, I used a realist evaluation drawing on Pawson and Tilley[98] to explain variation in programme implementation conducted within a trial environment. This approach allowed me to apply a realist philosophy of science to the explanatory component of the work.

7.7 Future research

7.7.1 Scaling up RHD screening in Australia

In Australia, the research questions related to RHD screening now move from the facility level to the system level. Future work will need to focus on the governance, policy, and funding arrangements required to support implementation across facilities. An important component of this will be a longer-term assessment of sustainability and more targeted evaluation of scale-up across Australia. Another key aspect will be expanding the costing work conducted in this thesis into a formal health economic evaluation, including cost effectiveness and budget impact analysis.

This future work will be conducted as a component of the NEARER ECHO (Non-Expert Acquisition and Remote Expert Review Echocardiography in Communities to Improve Health Outcomes) study. This study will be supported by a AU$5 million, 5-year grant awarded by the Australian Government's Medical Research Future Fund (GA434648). I am a chief investigator on this study.

7.7.2 Transferability to other programmes

At present, many RHD-endemic settings are considering implementing echocardiographic screening for the early detection of RHD. If countries adopt screening models that share features with the programme evaluated in this thesis, for example task sharing of image acquisition, opportunistic screening embedded in routine primary care, and remote expert review, further research could assess whether similar implementation challenges and enabling conditions are observed. Comparative work across settings could help clarify which aspects of the approach are likely to translate, which require adaptation, and what additional system supports are needed for sustainable delivery at scale. For example, in the ongoing ADUNU trial in northern Uganda, a similar echocardiographic screening programme to the one evaluated in this thesis is being implemented and evaluated, in which nurses and clinical officers (similar to physician associates) deliver both opportunistic and event-based screening alongside the introduction of a district-level RHD register[279].

Regarding the realist findings, the mechanism-led theorising enables testing in other evaluations by examining whether similar context-sensitive causal forces are triggered, and with what effects. This thesis offers an explanatory account of how outcomes were generated, with partial transferability because it specifies the contextual conditions that trigger these mechanisms. Cumulation can therefore occur if future realist evaluations incorporate these theories into their initial programme theory, either in other RHD echocardiographic screening programmes, or in programmes with similar core functions[98].

7.7.3 Monitoring and detecting carditis in acute rheumatic fever

Another important question that remains unanswered, and which will be addressed in the NEARER ECHO study, is whether this task-shared echocardiography model can improve detection of carditis in ARF, and support follow-up and monitoring echocardiography for people with prior ARF or early-stage RHD. Extending the model beyond RHD detection to ARF detection and longitudinal monitoring could increase the overall value of training and implementation investments.

7.7.4 Artificial intelligence for image interpretation

Work is underway to explore how artificial intelligence could support automated or assisted interpretation of echocardiographic images for RHD detection[280]. This is particularly relevant given my findings on delays in cardiology review, which may persist as screening expands and scan volumes increase. If validated and implemented safely, AI could help prioritise urgent cases, shorten turnaround times, and reduce specialist workload. Such an approach would require clear governance, local acceptability, and ongoing expert oversight. However, this thesis also highlights practical challenges for AI-enabled workflows. These include unreliable connectivity and the invisible work required to keep devices functioning. Future work should therefore assess not only diagnostic performance but also how and to what extent AI tools can be integrated into real-world settings, including data transfer, responsibility for follow-up, and any additional work shifted onto local staff.

7.7.5 Regression of early rheumatic heart disease

Finally, the findings of this thesis have implications for the emerging area of regression in early-stage RHD. As echocardiographic screening becomes more implementable, a larger proportion of RHD will be detected at an earlier, potentially more modifiable stage, shifting attention from case-finding alone to what can be done after diagnosis. In the GOAL trial, echocardiographic regression of latent (stage A) RHD at two years occurred in 195/399 participants (49%) assigned to secondary prophylaxis and 191/400 (48%) in the control group[20], highlighting both the frequency of regression and ongoing uncertainty about how best to influence it. Earlier detection therefore raises practical and scientific questions, including which disease phenotypes are most likely to regress, whether regression can be induced or accelerated with targeted immunotherapies, and how follow-up imaging intervals should be tailored to baseline risk and trajectory. Addressing these questions will likely require more sophisticated stratification that combines echocardiographic features with next-generation molecular approaches (for example, genomics, transcriptomics, proteomics, and metabolomics) to identify determinants of progression and biomarkers that can guide prognosis and personalised follow-up[281].

7.8 Conclusion

This thesis provides insights into how echocardiographic screening for RHD can be implemented in remote First Nations Australian communities. It synthesises implementation lessons from Australia's diabetic retinopathy screening programme and maps how a Theory of Change approach can be used to design and evaluate child health service programmes. It then reports work conducted with five remote First Nations communities to co-design and evaluate a task-sharing echocardiographic screening programme, drawing on qualitative, quantitative, and costing data. Taken together, the findings show that, under current conditions, embedding opportunistic screening within the routine work of First Nations community health workers is difficult to achieve. A more feasible approach could be a hybrid model that strengthens the local conditions for opportunistic screening, including building the legitimacy of the scanner role and supporting the invisible logistical and relational work required for delivery, while using periodic screening events and in-person visiting sonographer support to sustain coverage.

Appendices

A

Appendices for methods overview

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A.1 Implementation design discussion and field notes guide

Phrasing guide when discussing programme:

> We want to do better care for people in your community with rheumatic heart disease. We have a new way of doing an ultrasound picture of our heart for children and pregnant women. We use a handheld scanner about the same size as/looks a bit like a mobile phone. The ultrasound can find rheumatic heart disease early. Then we can start treatment for the best care. We want to work together with people here. We want to find the best ways that people think will make this heart ultrasound check up work in this place. When we find the best ways, we can share it with other communities and other health services.

In line with the yarning approach, the first step is to build a relationship with the participant by sharing stories, including your own story about who you are, where you come from, and why you are in the community to talk about rheumatic heart disease. Some questions to ask following this initial process:

- Who are you having the discussion with? e.g. role in community/clinic
- What are their ideas for the programme?
- Why will it work? (probing here for *rationale* e.g. 'trust', 'confidence', 'knowledge')
- How will it work? (what are the 'steps' involved? e.g. school screening, when, consent)
- How will you know it works? (probing here for *indicators* e.g. attendance)
- What *assumptions* are being made? (e.g. people get their check-up, secondary prophylaxis is available)
- What do you hope the program will achieve? (*outcomes*)

A.2 Example interview guide

Phase 2 interview guide for FNCHWs at Site 4

Introduction script guide:

> Thank you for your time. As you know we have been evaluating the NEARER SCAN programme to understand best ways to integrate it into usual care. We are specifically interested in finding out across the sites, what works, for whom, when, how, and why. If we can answer these questions, we can integrate the programme more successfully for more sites using what we have found.
>
> I was hoping to put a few suggestions of what we have found so far to you today and get your feedback. I would really love to hear what you think of these and encourage you to respond and challenge based on your experience, and by providing examples or counterexamples.
>
> It would not be helpful for us as an outcome of this evaluation to point out the hurdles to implementing the programme, you and we already know these (e.g. staff turnover, no time, limited resources). What we are interested in is: given these are present all the time, how come sometimes they stop people from scanning but other times people manage to scan despite them?

Questions

- We know that it has been quite hard for you to scan here in [Site 4]. We think that this might be because you have not had much support from the managers to scan. Do you think that is the case?
- In other sites, some things that have helped are when scanner colleagues refer patients for them to scan. Does this ever happen here?
- Do you think some of the things that have made it harder to scan here are not just about NEARER SCAN but about the clinic in general?
- Are you happy to talk about some of those issues?

- In some clinics the manager is the same for a long period, in others the manager and staff come and go. We think this makes it harder to integrate new programmes. What do you think about that?

- We saw that most people scanned seemed to be interested in learning more about their heart, for example the valves and RHD. Was this the case for the people you scanned? Were you able to have these discussions at the time?

A.3 Example focus group guide

Phase 2 focus group guide for doctors across sites

Participants: GP4, GP5, GPO, GPO(2)

Setting: Focus group discussion (approx. 90 minutes)

Tips for 'realist' interviewing

- At this stage, as the evaluation nears completion, focus on what has actually occurred in response to the statements read aloud, rather than what participants hope to see happen.
- Keep the discussion focused on reasons behind successful/unsuccessful implementation, rather than general thoughts and experiences.
- Use "what makes" or "what happens when" questions to elicit explanations (e.g. "What makes you feel hesitant to scan?").
- Use "what if" hypotheticals to explore variations (e.g. "What if you couldn't access the scanner, what would you do?").

Opening questions

- For GPO and GPO(2): Can you describe your experience with implementing NEARER SCAN in antenatal care at this hospital?
- For all: Compared to when NEARER SCAN first started, what changes (if any) have you noticed in how scanning fits into your routine care?
- For GPO and GPO(2): What do you think has contributed most to the success of NEARER SCAN at your site?

- For GPO and GPO(2): One of the things we have found so far in the remote sites is that even though we had envisioned scanning to be done opportunistically, there are many more scans performed during scheduled events. How have you found scanning opportunistically and tagging onto your antenatal check-ups? Why did this work?
- For GP4 and GP5: How do you find scanning opportunistically rather than scheduled screening? If easier for you than the FNCHWs, why?

Factors

When GPs build momentum in their scanning, a burst in scanning experience builds their confidence regardless of whether they have completed training, but confidence alone does not ensure they will continue scanning in practice.

- When did you start scanning more frequently? What was the relationship to finishing the 100 training scans and being assessed and passed as competent?

Patients are more likely to accept and complete an opportunistic scan when offered by a doctor rather than by a CHW or nurse, due to the perceived medical authority of doctors and implicit power dynamics.

- How do patients typically respond when you offer an echocardiographic scan during an antenatal visit?
- Some evidence suggests that patients feel a greater obligation to accept a scan when offered by a doctor, does this align with your experience?
- Are there situations where patients are more or less likely to accept an opportunistic scan? What influences this decision?

When scanning administration (e.g. device maintenance, uploads, troubleshooting) is not explicitly assigned, it falls to staff perceived as having more time, tech skills, or English proficiency, leading to frustration and workload imbalance.

- For GPO and GPO(2): In your experience, how has scanning-related administration (e.g. uploading images, device maintenance) been distributed among staff here?
- Do you feel that certain staff members have taken on a disproportionate amount of the administrative burden? If so, why do you think that happens?
- For GPO and GPO(2): What logistical or IT issues have come up when trying to integrate scanning into routine antenatal care? How have you worked around these barriers? Are these workarounds sustainable in the long term?

When devices are conveniently stored and charged, scanning feels more seamless and gets done more often.

- In a site where scanning is working well, how are logistics managed? Is there a 'best practice' model?

When CHWs or clinicians juggle multiple responsibilities, scanning gets deprioritised unless it is seamlessly integrated into workflows.

- For GPO and GPO(2): How do doctors balance scanning with other antenatal duties at this successful site?

Wrap-up question

- If you could change one thing to make scanning easier or more sustainable in your clinic, what would it be?

A.4 NoMAD survey

Survey instructions

This survey is designed to help understand how to integrate NEARER SCAN into usual care. It has three parts. Part A asks a few questions about you and your role. Part B includes three general questions about NEARER SCAN. Part C contains statements about NEARER SCAN with options to agree or disagree; where a statement is not relevant to you, please indicate why. Please select the option that best fits your experience for each question. The survey takes approx. 5–10 minutes.

Part A: About yourself

1. How many years have you worked for this clinic?	**< 1 yr**	**1–2 yrs**	**3–5 yrs**	**6–10 yrs**	**11–15 yrs**	**> 15 yrs**
Please tick one option	◯	◯	◯	◯	◯	◯

2. Your job category in relation to NEARER SCAN	**Please select one**
◯	I take the images of the heart using the handheld device (scanner).
◯	I review the images off-site (reviewer).
◯	I am a clinic manager at a site where NEARER SCAN is being implemented.
◯	I am a GP/nurse/community health worker/other involved in RHD care but not scanning or reviewing for NEARER SCAN.

Continues on next page.

Part B: General questions about the programme

How used to NEARER SCAN do you feel?

Still feels very new — Feels completely normal

0 1 2 3 4 5 6 7 8 9 10

Do you remember that you can do (if scanner), or check in about (if manager) NEARER SCAN everyday?

Not at all — Somewhat — Completely

0 1 2 3 4 5 6 7 8 9 10

Do you think you will be able to remember you can do NEARER SCAN everyday?

Not at all — Somewhat — Completely

0 1 2 3 4 5 6 7 8 9 10

Continues on next page.

Part C: Detailed questions about the programme

Statement	Strongly agree	Agree	Neither	Disagree	Strongly disagree	Not relevant to my role	Not relevant at this stage	Not relevant to program
I can see how NEARER SCAN is different from other work.	◯	◯	◯	◯	◯	◯	◯	◯
Staff in this clinic have a shared understanding of the purpose of NEARER SCAN.	◯	◯	◯	◯	◯	◯	◯	◯
I understand how NEARER SCAN changes the way I do my work.	◯	◯	◯	◯	◯	◯	◯	◯
I can see the value of NEARER SCAN for my work.	◯	◯	◯	◯	◯	◯	◯	◯
There are key people who help lead NEARER SCAN at the clinic and get others involved.	◯	◯	◯	◯	◯	◯	◯	◯
I see taking part in NEARER SCAN as part of my role.	◯	◯	◯	◯	◯	◯	◯	◯

Statement	Strongly agree	Agree	Neither	Disagree	Strongly dis-agree	Not relevant to my role	Not relevant at this stage	Not relevant to the program
I'm happy to try new ways of working with others to use NEARER SCAN.	◯	◯	◯	◯	◯	◯	◯	◯
I will continue to support NEARER SCAN.	◯	◯	◯	◯	◯	◯	◯	◯
It's easy for me to fit NEARER SCAN into my work day.	◯	◯	◯	◯	◯	◯	◯	◯
NEARER SCAN makes it harder for people to work well together.	◯	◯	◯	◯	◯	◯	◯	◯
I have confidence in other scanners to use NEARER SCAN well.	◯	◯	◯	◯	◯	◯	◯	◯
When a scan needs to be done, others expect it is me that does the scan.	◯	◯	◯	◯	◯	◯	◯	◯
We get enough training to help us use NEARER SCAN.	◯	◯	◯	◯	◯	◯	◯	◯
We have all the equipment we need to do NEARER SCAN well.	◯	◯	◯	◯	◯	◯	◯	◯

Statement	**Strongly agree**	**Agree**	**Neither**	**Disagree**	**Strongly dis-agree**	**Not relevant to my role**	**Not relevant at this stage**	**Not relevant to the program**
Management supports NEARER SCAN.	○	○	○	○	○	○	○	○
I know there are updates or stories about how NEARER SCAN is going.	○	○	○	○	○	○	○	○
Most people at work agree NEARER SCAN is worth doing.	○	○	○	○	○	○	○	○
I value the effects that NEARER SCAN has had on my work.	○	○	○	○	○	○	○	○
Feedback about NEARER SCAN can be used to improve it in the future.	○	○	○	○	○	○	○	○
I can change how I work with NEARER SCAN.	○	○	○	○	○	○	○	○

B

Appendices for literature reviews

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B.1 Scoping review screening guide

Screening guide used for eligibility assessment

1. Health service programme?	2. Target age 0–19?	3. Theory of Change?
Is it a new programme, or changes to an existing programme (e.g. funding, staffing, delivery mode)?	Are more than half of the programme's target years between 0–19 (e.g. 10–22)?	Is there a mention of a ToC, logic model, or synonymous term? Or, is there mention of how and why an intervention should work?
Is the programme being delivered by a health service (e.g. hospital, community health worker, or primary health centre)?	–	–

B.2 Scoping review extracted data

Data extraction of scoping review (table adapted to fit landscape)

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Barnhart et al. 2022[282], BetterBirth Program (India)	A tool that defines and expresses researchers' underlying assumptions and hypotheses about the processes through which a complex intervention improves outcomes.	Developed retrospectively through review of study materials and refined in discussion with the BetterBirth team. Led by programme evaluators and implementers, with acknowledgement that prospective engagement of community members and frontline healthcare providers would offer additional contextual insight and strengthen community buy-in.	Diagram (logic model), post	Used to prioritise data collection and guide analysis, identify ineffective components or incorrect assumptions about rationale or context, and strengthen collaboration across interdisciplinary teams by creating a shared understanding of the intervention.	Developing a robust ToC earlier in the process would have exposed key limitations, supported more complete data collection, and created opportunities to learn about the intervention's strengths and weaknesses. Identified three lessons for future complex intervention work: the importance of a robust ToC, the need to define optimisation outcomes and success criteria, and the value of capturing variation in implementation intensity.	-	C, O, I, A
Chandani et al. 2014[283], Supply Chains for Community Case Management (Ethiopia, Malawi, Rwanda)	Provides a framework for identifying solutions and innovations, monitoring change and demonstrating success through a visual representation of steps.	-	Diagram, pre	Supports project assessment, guides identification of needed interventions, informs monitoring and evaluation, and helps develop hypotheses and causal pathways for change.	-	-	C, O, I, A

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Chandani et al. 2017[284], Future Health Systems (Bangladesh, India, Uganda)	A management tool applying critical thinking to the design, implementation and evaluation of initiatives intended to support change in context.	FHS developed ToCs in 2011 across five countries. Bangladesh, India and Uganda revised their ToCs mid-implementation (2013–2014). Stakeholders included country team representatives, Johns Hopkins Bloomberg School of Public Health and the Institute of Development Studies; site-level personnel are detailed in the article.	Diagram, pre	To test assumptions and pathways of change, guide data collection and explain observed impacts.	Facilitated clearer communication within teams and with stakeholders; most useful at country-site level. In Bangladesh it guided policymaker engagement and participatory community dialogue, surfacing assumptions; mid-course refocusing reflected double-loop learning.	Revision prompted reassessment of assumptions in light of evidence. Revised ToCs showed stronger feedback across components, actors and outcomes. Teams noted the importance of dedicated reflection points as ongoing adjustments were frequent.	C, O, I*, A
Cordova-Pozo et al. 2018[285], Community-embedded reproductive healthcare for adolescents (Bolivia, Ecuador, Nicaragua)	Explains how a project will achieve a series of outcomes by outlining causal relations based on assumptions to reach behaviour change.	-	Diagram (logic model), post	-	-	-	C, O, I*, A
Darmstadt et al. 2020[286], Ananya (India)	-	-	Diagram (logic model), pre	-	-	-	C, O
Daruwalla et al. 2019[287], Society for Nutrition, Education and Health Action (India)	ToC is a hypothetical explanation of how and why an initiative works, seeking to understand how programme activities might lead to outcomes—desired or undesired—by articulating connections between them.	Developed through a five-phase, iterative process combining consultations with programme teams, a research workshop with external experts, workshops with the core team and data collectors, incorporation of action-documentation and gender-norms studies, and repeated backward-mapping sessions. External activists, academics and practitioners contributed through review workshops.	Diagram, during	-	-	-	C, O, R, I, A

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
DiLiberto et al. 2015[288], PRIME malaria care intervention (Uganda)	Used programme and implementation-theory approaches to explain how and why PRIME components were hypothesised to combine to produce desired outcomes, with programme theory focusing on "why" and implementation theory on "how".	-	Theory and logic model, pre-intervention phase	Not defined explicitly.	-	-	C, O, R
Faiz et al. 2019[289], Handover tool (Pakistan)	ToC is a methodology enabling stakeholders to articulate their long-term goals and the preconditions required to achieve them.	Following initial observations, the primary team and stakeholders developed a ToC framework. The long-term goal was defined as achieving complete and concise information transfer during postoperative cardiac surgery handover. Short-term outcomes and necessary preconditions were mapped backwards from this goal. Indicators were defined to measure whether expected changes were occurring.	Diagram, pre	-	In a survey, all respondents reported that the ToC method allowed quicker implementation of the handover protocol.	-	C, O, I*
Fietchner et al. 2018[290], Adolescent 360 (reproductive health) (Ethiopia, Nigeria, Tanzania)	Not clearly defined; closest description is a theory-guided evaluation design describing how A360 leads to change, as part of a broader process evaluation.	-	Diagram, pre	To understand how and why the intervention worked, generate lessons for future policy and practice, and test causal links.	-	ToC was reviewed iteratively, consistent with the human-centred design approach.	C, O, R*, A*
Fiechtner et al. 2021[291], Healthy Weight Clinic Paediatric Weight Management Intervention (USA)	-	-	Logic model, pre-intervention phase	-	-	-	C, O, A

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Fuhr et al. 2020[292], Problem Management Plus (PM+) and Early Adolescent Skills for Emotions (EASE) (Turkey, Netherlands, Lebanon)	ToC described as a project-planning tool to understand the change process of an intervention and map causal pathways by presenting the preconditions needed to achieve long-term outcomes and ultimate impact.	Country-specific ToCs were developed through workshops bringing together academics, mental-health professionals, NGOs, community health workers and government officials in each country.	Diagram (ToC diagram), pre-intervention phase	Used to unpack complex mental-health interventions and to enhance stakeholder involvement and joint planning for scale-up.	Provided a structured means of working with stakeholders to explore assumptions, understand reasons for success or failure, and unpack the complexity of scaling up; also suggested as a tool for monitoring and evaluation over time.	Recognised that parts of the map may become obsolete as circumstances change, but the flexible approach allows updating and alignment of intermediate outcomes with indicators for ongoing monitoring.	C, O, R*, I, A
Gadsby et al. 2020[293], Go-Golborne childhood obesity programme (UK)	ToC clarified the programme's aims, objectives and outcomes and articulated the assumptions underlying the programme design.	-	Diagram (basic ToC diagram), post-intervention phase	-	-	-	C, O, I*
Greenland et al. 2017[294], Komboni Housewives diarrhoea-control intervention (Zambia)	-	-	Diagram (basic ToC diagram), post-intervention phase	Provided a framework for structuring data collection along the hypothesised causal pathway for the multiple-component behaviour-change intervention.	Helped ensure that qualitative and quantitative data were collected on key links in the programme theory, including dose delivered, reach, recruitment and fidelity, so that the pathway to diarrhoea outcomes could be assessed.	-	C, O, A
Gupta et al. 2017[295], National Rural Health Mission (India)	ToC is essentially a comprehensive description and illustration of why and how a particular change is expected to happen in a particular context, leading to desired goals.	-	Diagram (logic model), post	-	-	-	C, O

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Hanley et al. 2021[296], Kooth online mental-health support (UK)	Describes an outcomes-based ToC that can be used to identify and evaluate how programmes and services achieve their stated goals, defined as the description of a sequence of events expected to lead to a particular desired outcome.	Used a five-step design process that started with defining a realistic long-term goal, then worked backwards to identify intermediate outcomes, their causes and effects, and indicators.	Narrative bullet-point ToC, during intervention phase	Framed as a collaborative process that helps surface hidden perspectives, clarifies what needs to be measured, and can be used both retrospectively to evaluate a service and prospectively to plan similar programmes.	Served as an informative training tool for professionals in a web-based support environment and as a heuristic for designing bespoke tools to capture outcomes of humanistic web-based support.	-	C, O
Hanson et al. 2019[297], Safe Care, Saving Lives (SCSL) (India)	-	-	Diagram (logic model), pre	-	-	-	C, O, I
Harrington et al. 2021[298], PRE-STARt interactive lifestyle programme (UK, Portugal, Greece, Germany, Spain)	-	-	Logic model, pre-intervention phase	-	-	-	C, O, R
Hernandez and Hodges 2006[175], Contra Costa County child mental-health intervention (USA)	ToC used to articulate underlying beliefs and assumptions guiding development and implementation of the interagency strategy, conceptualising characteristics of the population, desired outcomes and strategies to achieve them, and the relationships between these elements.	Developed with high-level administrators, middle managers, education-system representatives, family representatives, service coordinators, management staff and evaluators working together.	ToC logic model, pre-intervention phase	Guided coordination of multiple programmes and services into a cohesive strategy and provided a tool for planning implementation.	Helped organise ideas into components, document what stakeholders believed central to the strategy, and build consensus; served as an ongoing point of reference for the system over time.	Acknowledged as valuable precisely because it could be revisited as a reference point for assessing strategic direction.	C, O, I*, A*

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Hurtubise, Brousselle, Camden 2020[174], Intensive Interdisciplinary Pain Treatment (Canada)	Programme theory defined as the specific activities by which an intervention achieves its anticipated outcomes.	Constructed using a three-step logic analysis approach. Document analysis, stakeholder surveys and group discussions supported development of a draft logic model covering resources, activities, processes, outcomes and contextual factors. A 13-member expert panel (clinicians, teachers, managers, youth with pain-related disability and parents) participated in six meetings.	Diagram (logic model), during	Supports stakeholder engagement and uncovers causal pathways that may be present but not immediately visible. Helps reduce uncertainty about the programme theory and provides an early assessment of its theoretical and empirical foundations.	Provided a shared understanding of intervention complexity and revealed previously unrecognised intervention–context interactions. Standardised approach helped theorise the programme, surfaced beliefs about causal mechanisms and integrated integrative knowledge transfer.	-	C, O, R**
Kabongo et al. 2020[299], MomConnect programme (South Africa)	Defines ToC as a way to make underlying assumptions explicit by setting out inputs, outputs, outcomes and impact, which can be used both as a product (diagram or narrative) and as a process to show how a goal will be reached.	-	Diagram (basic ToC diagram), during interven-tion phase	Clarified the different modalities of the MomConnect programme, articulated short- and long-term intended outcomes, and mapped tentative causal links to show how these outcomes were expected to be achieved.	Supported explication of the implementation theory for planning and improvement and underpinned development of monitoring systems, but was noted as linear, time- and resource-intensive and challenging when multiple perspectives and unexpected outcomes arose.	Developed iteratively, moving back and forth between data, the ToC and programme theory through regular author meetings.	C, O, R*
Kung'u et al. 2017[300], Community-based Maternal and Neonatal Health and Nutrition (Ethiopia, Kenya, Niger, Senegal)	-	-	Diagram (logic model), during	-	-	-	C, O, I*

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Lalli et al. 2018[301], Saving Lives at Birth programme (multi-country)	A comprehensive description of how and why a desired change is intended to happen, mapping out steps required to achieve long-term goals.	Developed through a literature review assessing gaps in existing tools, incorporation of technical and policy expert input and iterative refinement through consultations with partners.	Diagram, post	Enables use of ToC to plan interventions, guide monitoring and evaluation, strengthen stakeholder engagement and describe how a process works in evidence-based policy and practice.	Mapped out pathways across multiple actors and highlighted areas where the programme excelled or was vulnerable; supported structured reflection, organisational learning and improved strategy.	Iteratively refined through workshops where innovators contributed to shaping the model; recognised as a dynamic tool supporting critical thinking throughout the programme cycle.	C, O, I*, A*
MacKenzie et al. 2005[173], Starting Well (Scotland)	The ToC mapped stakeholders' views of how and why the intervention operated and captured programme progression during a three-year period of activity.	Developed iteratively through collaboration between the evaluator and strategic-level staff over one year. The process involved linking aims, outcomes and contextual factors across the initiative.	Process description, pre	Highlighted multiple and broad goals, difficulties in measuring activities and limitations of traditional experimental designs; supported project planning and identification of data needs and appropriate methods.	Included reflections on the ToC's meaningfulness, noted tensions between medical expectations and project aims, and highlighted how success metrics influenced implementation focus.	Revisited by the original group to assess whether the project was viewed as successful and whether the ToC remained meaningful in retrospect.	-
Makowiecka et al. 2019[302], Overarching ToC for 61 interventions (Nigeria, Ethiopia, India)	Described as an iterative and participatory tool to examine assumptions, foster learning and map a logical programme pathway from activities to outcomes.	-	Mixed (theory and logic model)	-	Enabled stakeholders, policymakers and evaluators to identify what innovations were implemented, where and when. Supported use of common measures and helped identify gaps, overlaps and issues relevant to scale-up.	-	C, O

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Mbuthia et al. 2021[303], Mobile-health communication for postnatal care (Kenya)	Describes a sequence of related elements comprising influencing factors, problems, community needs, strategies and expected outcomes. The model visually links strategies with specific factors to address community needs.	Stakeholder engagement followed a forward- and backward-mapping process, clarifying logic and linkages. Additional comments were incorporated as needed. Rigour was assessed using a Kellogg Foundation checklist, and the final framework was verified by all stakeholders after revision.	Diagram (logic model), pre	Useful for informing policymakers about critical programme mechanisms.	Enabled researchers to describe the desired results of mHealth communication in rural Kenya.	Iterative process.	C, O, A
Mei et al. 2017[304], Micronutrient supplementation (multi-country)	-	-	Diagram (basic ToC diagram), pre	-	-	-	C, O, I
Michaud-Létourneau, Gayard, Pelletier 2018[305], Alive & Thrive (breastfeeding advocacy) (Cambodia, Indonesia, Lao PDR, Myanmar, Thailand, Timor-Leste, Vietnam)	-	Developed as part of a broader contribution analysis, beginning with an initial ToC derived from a Vietnam logic model. The final contribution story was produced by verifying assumptions underpinning three key linkages in the ToC.	Diagram, post	Provided a systematic way to make evidence-based causal claims in settings not suited to conventional experimental or statistical methods.	Used to compare findings across countries applying the same advocacy model, strengthening external validity and generalisability.	-	C, O, A

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Milner et al. 2019[306], Saving Brains (multi-country, LMICs)	-	-	Diagram, pre	-	Early consideration of pathways to impact and scale was supported by a ToC approach. Stakeholders valued the ToC for forward planning, though practical situational analysis tools and local data to guide these processes were lacking.	-	C, O, I
Nimpagaritse, Korachais, Meessen 2020[307], Childhood malnutrition programme (Burundi)	-	-	Diagram (logic model), during	-	Used to compare results across several countries using the same advocacy approach, reinforcing external validity and generalisability of the ToC.	-	C, O
Oliwa et al. 2020[308], Tuberculosis case detection (Kenya)	-	-	Diagram, pre	-	-	-	C, O, R
Rasheed et al. 2021[309], Play-based psychosocial intervention (Pakistan)	-	-	Diagram, pre	-	-	-	C, O, A
Sarma et al. 2019[310], Measles–Rubella campaign (Bangladesh)	An analytical framework for defining ideal programme-implementation milestones and indicators to compare with actual processes.	-	Diagram, post	-	-	-	C, O, I*

Table continued from previous page

Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
Satherley et al. 2019[311], Children and Young People's Health Partnership (CYPHP) Evelina London Model of Care (UK)	-	-	Theoretical framework (basic ToC diagram), post-intervention phase	-	-	-	C, O, R, A
Seward et al. 2022[312], ASSET health-system strengthening (Ethiopia, Sierra Leone, South Africa, Zimbabwe)	-	Initial ToC developed in the pre-implementation phase through one to three workshops led by each work-package team. Subsequent workshops during implementation were used to adapt and refine the programme theory as learning accumulated. Stakeholders included community representatives, health extension workers, primary and secondary care clinicians, managers and other cadres, invited according to each work package.	Process description, pre	-	-	-	ToC not presented
Van Belle et al. 2010[313], PASSAGE programme (Mali, Burkina Faso, Cameroon)	-	Developed through a detailed theory-driven evaluation process including assessing scope and appropriateness, reconstructing the initial programme theory, choosing data-collection methods, assessing relevance and implementation, establishing causal mechanisms and contextual factors, and translating findings into a refined programme theory.	Causal web diagram, pre	-	-	Revisited to refine programme theory.	C, O, R, A*

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Details	ToC definition	Development & stakeholders	Output & stage	Purpose	Value	Refinement	Comp.
van der Merwe et al. 2021[314], Verbal Autopsy with Participatory Action Research (VAPAR) programme (South Africa)	Programme ToC articulates the complex interplays between context, mechanisms of change and outcomes.	-	Diagram (logic model), during	-	-	-	C, O, R
Wilbur et al. 2018[315], Hygiene for People with Disabilities (Nepal and Malawi)	Pragmatic ToC framework describing how an intervention is expected to influence change, developed collaboratively with key stakeholders and including hypothesised causes and effects leading to intended impact.	Developed through workshops where participants worked in mixed groups. Research on barriers informed discussions, followed by backward mapping from long-term goals to outcomes, identification of activities and prioritisation of activities based on feasibility, acceptability and sustainability.	Diagram, pre	-	Supported findings that stakeholder engagement helps identify context-specific solutions and ensured a shared understanding of goals. Highlighted how ToC can inform future design and clarify assumptions for culturally appropriate interventions.	-	C, O, R
Zamboni et al. 2021[316], Safe Care, Saving Lives (India)	ToC used to understand how contextual factors influenced implementation and the hypothesised mechanisms of change.	Developed initially through a participatory workshop with programme implementers.	Diagram, post	Used to conceptualise individual and organisational changes and identify potential bottlenecks.	-	Refined by integrating relevant theory and informed by a systematic review.	C, O, R

ToC = Theory of Change, Comp. = components of Theory of Change, C = context, O = outcome, R = rationale, I = indicator, A = assumption.

C

Appendices for implementation design

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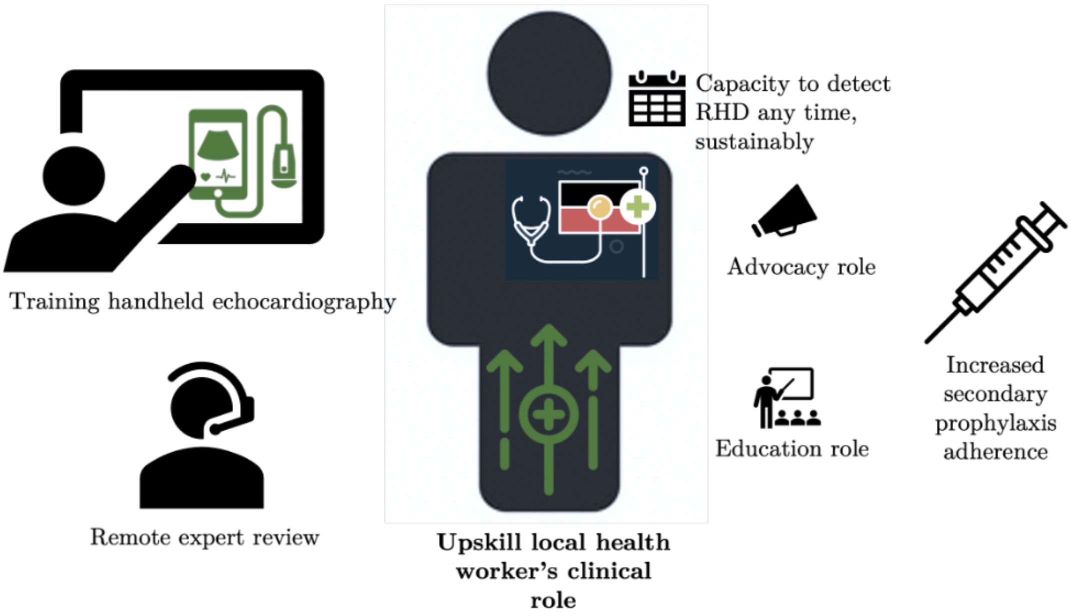
C.1 Programme function representation



D

Appendices for process evaluation

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D.1 Costing workbook

An example costing workbook sheet is shown below, illustrating the training and initial set-up component and underlying assumptions. The full costing workbook has been published open access for transparency and is available at:
https://doi.org/10.5281/zenodo.17611625.

Personnel costs								
Stage of training	**Actions**	**Temporality**	**Actors**	**Action frequency**	**Action duration (hours)**	**Total time spen on action (hours)**	**Minimum total time spent on action (-20%)**	**Maximum total time spent on action (+20%)**
Planning	Site-specific planning meetings and coordination overhead	Pre-implementation, ≈ 3 meetings per site x 5 sites = 15	Project coordinator	15	2	30	24	36
			Clinic manager	15	1	15	12	18
			Principal investigator	15	1	15	12	18
	Internal implementation team meetings and coordination overhead (e.g. work done outside meetings to prepare for meetings, actioning follow-ups)	Pre-implementation, ≈ 3 meetings per site x 5 = 15	Project coordinator	15	2	30	24	36
			Sonographer	15	1	15	12	18
			Principal investigator	15	1	15	12	18
	Coordination e.g. lists, sheets, name tags etc.	Pre-implementation, once-off	Project coordinator	5	2	10	8	12
			Implementation team assistant (for NEARER SCAN this was a research assistant)	5	2	10	8	12
	Adapting presentation for local communtiy e.g. updating slides	Pre-implementation, once-off	Sonographer	5	1	5	4	6
Training	The in-person training itself	Implementation, per day	Sonographer x2 x 4 days	5	64	320	256	384
			Training assistant (researcher) x1 x 4 days	5	32	160	128	192
			First Nations community health workers x 4 (average trainee make up across sites) x 4 days	5	128	640	512	768
			Nurse x 1 (average trainee make up across sites) x 4 days	5	32	160	128	192
			GP x 1 (average trainee make up across sites) x 4 days	5	32	160	128	192
Total personnel costs								

Actor wage rate (per hour)	Actor wage rate (per hour) loaded	Minimum actor wage rate	Minimum actor wage rate (loaded)	Maximum actor wage rate	Maximum actor wage rate (loaded)	Total cost	Loaded rate (incl. on-costs)	Minimum cost	Maximum cost	Personnel time - 20%	Personnel time +20%	Wage rate minimum	Wage rate maximum
$ 52	$ 68	$ 50	$ 66	$ 55	$ 72	$ 1,560	$ 2,044	$ 1,200	$ 1,980	$ 1,635	$ 2,452	$ 1,965	$ 2,162
$ 68	$ 89	$ 67	$ 88	$ 69	$ 90	$ 1,020	$ 1,336	$ 804	$ 1,242	$ 1,069	$ 1,603	$ 1,317	$ 1,356
$ 102	$ 134	$ 102	$ 134	$ 102	$ 134	$ 1,530	$ 2,004	$ 1,224	$ 1,836	$ 1,603	$ 2,405	$ 2,004	$ 2,004
$ 52	$ 68	$ 50	$ 66	$ 55	$ 72	$ 1,560	$ 2,044	$ 1,200	$ 1,980	$ 1,635	$ 2,452	$ 1,965	$ 2,162
$ 56	$ 73	$ 53	$ 69	$ 64	$ 84	$ 840	$ 1,100	$ 636	$ 1,152	$ 880	$ 1,320	$ 1,041	$ 1,258
$ 102	$ 134	$ 102	$ 134	$ 102	$ 134	$ 1,530	$ 2,004	$ 1,224	$ 1,836	$ 1,603	$ 2,405	$ 2,004	$ 2,004
$ 52	$ 68	$ 50	$ 66	$ 55	$ 72	$ 520	$ 681	$ 400	$ 660	$ 545	$ 817	$ 655	$ 721
$ 46	$ 60	$ 36	$ 47	$ 53	$ 69	$ 460	$ 603	$ 288	$ 636	$ 482	$ 723	$ 472	$ 694
$ 56	$ 73	$ 53	$ 69	$ 64	$ 84	$ 280	$ 367	$ 212	$ 384	$ 293	$ 440	$ 347	$ 419
$ 56	$ 73	$ 53	$ 69	$ 64	$ 84	$17,920	$ 23,475	$ 13,568	$ 24,576	$ 18,780	$ 28,170	$ 22,218	$ 26,829
$ 71	$ 93	$ 67	$ 88	$ 77	$ 101	$11,360	$ 14,882	$ 8,576	$ 14,784	$ 11,905	$ 17,858	$ 14,043	$ 16,139
$ 35	$ 46	$ 27	$ 35	$ 40	$ 52	$22,400	$ 29,344	$ 13,824	$ 30,720	$ 23,475	$ 35,213	$ 22,637	$ 33,536
$ 65	$ 85	$ 36	$ 47	$ 96	$ 126	$10,400	$ 13,624	$ 4,608	$ 18,432	$ 10,899	$ 16,349	$ 7,546	$ 20,122
$ 113	$ 148	$ 108	$ 141	$ 137	$ 179	$18,080	$ 23,685	$ 13,824	$ 26,304	$ 18,948	$ 28,422	$ 22,637	$ 28,715
						$89,460	**$ 117,193**	**$ 61,588**	**$ 126,522**	**$ 93,754**	**$ 140,631**	**$ 100,850**	**$ 138,120**

Non-personnel costs

Support costs	**Description of expense**	**Quantity**	**Unit cost**	**Total cost**	**Minimum cost (-20%)**	**Maximum cost (+20%)**
Travel	Flight expenses were for 7 trainees and 8 trainers for training 4 sites. To cost for 5 sites we therefore multiplied by 1.25.	1.25	$ 17,106	$ 21,383	$ 17,106	$ 25,659
Accomodation	Accommodation expenses were for 7 trainees and 8 trainers for training 4 sites. To cost for 5 sites we therefore multiplied by 1.25.	1.25	$ 7,445	$ 9,306	$ 7,445	$ 11,168
Training lunch and refreshments costs	Lunch and refreshment costs for trainees of 2 sites. It represents five invoices for supplies from a local bakery, the local grocery store in the Site where supplies were purchased.	2.5	$ 650	$ 1,625	$ 1,300	$ 1,950
Travel allowance	Paid to training staff for the training across the 4 sites. To cost for 5 sites we therefore multiplied by 1.25.	1.25	$ 435	$ 544	$ 435	$ 653
Total support costs				$ 32,858	$ 26,286	$ 39,429

Equipment	**Description of expense**	**Quantity**	**Unit cost**	**Total cost**	**Useful life (years)**	**Minimum cost (-20%)**	**Maximum cost (+20%)**
Philips Lumify device		12	$ 8,045	$ 96,540	5	$ 77,232.0	$ 115,848.0
Samsung S6 Tablet		12	$ 500	$ 6,000	5	$ 4,800.0	$ 7,200.0
Cloud-based software platform license	Fixed cost charged per scan. Based on 12 months of scan usage, extrapolated from 360 scans completed over a 14-month observation period. These scans represent scans conducted across the five remote sites for children and	308	$ 2	$ 616	N/A	$ 492.8	$ 739.2
Wifi dongles		5	$ 77	$ 385	5	$ 308.0	$ 462.0
SIM data plans for dongles	Across the 5 sites the total monthly cost was $156	12	$ 156	$ 1,872	N/A	$ 1,497.6	$ 2,246.4
Total equipment costs				$105,413		$ 84,330	$ 126,496
Total non-personnel costs				**$138,271**		**$ 110,616**	**$ 165,925**

Personnel	Data sources and assumptions	Source
Project coordinator	Salary and workforce data and researcher estimate validated with staff self-report. Assumed Level 7 Step 2 Professional, Administrative and Technical Employees.	https://www.fwc.gov.au/document-search/view/3/aHR0cHM6Ly9zYXNyY2RhdGFwcmRhdWVhYS5ibG9iLmNvcmUud2luZG93cy5uZXQvZW50ZXJwcmlzZWFncmVlbWVudHMvMjAyMy84L2FlNTIxMzI5LnBkZg2?sid=&q=menzies%24%24school%24%24health%24%24Research#
Clinic manager	Salary and workforce data and researcher estimate. Assumed median offered salary in job description.	https://www.naccho.org.au/job/registered-nurse-health-centre-manager-ramingining-nt/
Principal investigator	Salary and workforce data and researcher estimate validated with staff self-report. Assumed Level E professor.	https://www.fwc.gov.au/document-search/view/3/aHR0cHM6Ly9zYXNyY2RhdGFwcmRhdWVhYS5ibG9iLmNvcmUud2luZG93cy5uZXQvZW50ZXJwcmlzZWFncmVlbWVudHMvMjAyMy84L2FlNTIxMzI5LnBkZg2?sid=&q=menzies%24%24school%24%24health%24%24Research#
Sonographer	Salary and workforce data and researcher estimate validated with staff self-report. Assumed sonographer Grade 3 Year 1.	https://vahpa.asn.au/wp-content/uploads/2023/01/AHP-Vic-Public-Sector-Single-Interest-Employers-EA-2021-26.pdf
Implementation team assistant (for NEARER SCAN this was a research assistant)	Salary and workforce data and researcher estimate validated with staff self-report. Assumed Level A RA Step 4.	https://www.fwc.gov.au/document-search/view/3/aHR0cHM6Ly9zYXNyY2RhdGFwcmRhdWVhYS5ibG9iLmNvcmUud2luZG93cy5uZXQvZW50ZXJwcmlzZWFncmVlbWVudHMvMjAyMy84L2FlNTIxMzI5LnBkZg2?sid=&q=menzies%24%24school%24%24health%24%24Research#
Training assistant (for NEARER SCAN this was a researcher)	Salary and workforce data and researcher estimate validated with project records. Assumed Level 3 SRF3.	https://www.fwc.gov.au/document-search/view/3/aHR0cHM6Ly9zYXNyY2RhdGFwcmRhdWVhYS5ibG9iLmNvcmUud2luZG93cy5uZXQvZW50ZXJwcmlzZWFncmVlbWVudHMvMjAyMy84L2FlNTIxMzI5LnBkZg2?sid=&q=menzies%24%24school%24%24health%24%24Research#
First Nations community health worker	Salary and workforce data and researcher estimate validated with project records. Asssumed Grade 4 Level 1.	https://www.fairwork.gov.au/employment-conditions/awards/awards-summary/ma000115-summary
Nurse	Salary and workforce data and researcher estimate validated with project records. Assumed Level 4.2.	https://ocpe.nt.gov.au/media/documents/nt-public-sector-employment-information-about-ntps-employment/information-about-ntps-employment/ntps-nurses-and-midwives-2022-2026-enterprise-agreement.PDF
General Practitioner	Salary and workforce data and researcher estimate validated with project records. Assumed RG2.	https://ocpe.nt.gov.au/employment-terms-and-conditions/rates-of-pay/medical-officers
Cardiologist	Salary and workforce data and researcher estimate. Assumed SMO1.4.	https://ocpe.nt.gov.au/employment-terms-and-conditions/rates-of-pay/medical-officers
Administrative officer	Salary and workforce data and researcher estimate. Assumed median offered salary in job description.	https://miwatj.applynow.net.au/jobs/MHAC567-administration-officer-raypirri-rom-100943
Site champion (at clinic manager level)	Salary and workforce data and researcher estimate. Assumed median offered salary in job description.	https://www.naccho.org.au/job/registered-nurse-health-centre-manager-ramingining-nt/
Senior primary school teacher liaison	Salary and workforce data and researcher estimate. Assumed ST4.	https://ocpe.nt.gov.au/employment-terms-and-conditions/rates-of-pay/teachers-and-educators

D.2 Implementation strategies

Implementation strategies

Implementation strategy*	Sites	Activities delivered (including adaptations)	Programme components	Evidence of contribution to programme component or shortfalls
Audit and provide feedback	All sites	Informal feedback was inconsistent early in implementation due to limited NEARER SCAN study team capacity. In 2025, with the employment of a research assistant, a bimonthly email was introduced, providing scanners and facility managers with reports summarising scan numbers, results, and uninterpretable rates, and a live progress dashboard link they could access at anytime.	Cross-cutting	Turnover among facility managers limited the reach of feedback provided to facilities: “I don’t get any feedback” [CM4]. When scan reports were sent, they did not appear to prompt broader engagement or follow-up action. As one scanner [GP5] noted, “It’s easy to send an email to the clinic manager... But then, it’s the next step – how does the manager actually build that into their programme? Is there regular check-ins? I think that’s the next step. That is not being done here.” The theory that reporting progress would motivate managerial support and wider dissemination of feedback within facilities therefore might not hold in practice.
Build a coalition	Sites 2 & 3	At Site 2, scanners organised to scan alongside a local event promoting sport in youth. At Site 3, scanners integrated scanning into a twice-yearly public health event involving multiple community services.	Community engagement and staff training	Building a coalition was noted to increase scanning opportunities, facilitating staff training. One staff member reflected, “That’s the good thing about [Site 3] too, all the other service providers get on board” [N3(3)], while another noted that community-led programmes actively involved scanners in their activities: “That’s support we get from [local active youth programme] that’s been running. He involves us to do scanning along with his programme” [FGFNCHW2(2)]. The visibility of scanning activities was further amplified through community Facebook posts, with one nurse commenting, “When we were [scanning] at the Youth Centre, they put it on Facebook, and then some of the girls came, [and said] ‘oh, we seen it on Facebook’” [2FGN3(2)].
Capture & share local knowledge	All sites	Organised a community-of-practice workshop in Darwin for all scanners to share experiences.	Staff training	Report from event shared with stakeholders. Informal end of workshop surveys suggested it was of benefit to scanners.
Celebrate graduation (including providing identifiable scanner clothing)	Sites 1, 2, 3, 5	Scanners were provided with a certificate and a locally designed NEARER SCAN scanner polo shirt upon completion of their training.	Staff training	This strategy appeared to contribute to scanner pride and visibility within clinics. One scanner who had just graduated was observed introducing themselves at an all-staff morning meeting by saying, “My name is [FNCHW3], I’m a community health worker, and also I’m a NEARER SCANNER, and I’m so excited to do some scans today, wearing this new deadly shirt I’ve got” [OFN1], suggesting visible recognition of their role. Another observer at a different site noted, “Afternoon tea with the others in the clinic, clinic manager, AHPs, nurses to celebrate [FNCHW2]... All very proud and supportive” [OFN2]. There was no direct evidence it contributed to staff training outcomes.

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Implementation strategy*	Sites	Activities delivered (including adaptations)	Programme components	Evidence of contribution to programme component or shortfalls
Centralise technical assistance	All sites	Communication support from off-site cardiac sonographers was attempted through WhatsApp groups for each site, but engagement was limited. Scheduled video 'check-in' calls were trialled at some sites but not sustained. In practice, technical assistance was primarily delivered in-person during site visits.	Handheld device and image upload	Off-site technical assistance was inconsistently implemented. One sonographer commented, "Checking in with the non-experts in [Site 3] has not made any apparent difference in the past" [OFN3], highlighting a perceived lack of effect over multiple attempts. This suggests a potential shortfall both in implementation and in the underlying theory that centralised assistance would strengthen scanner capability in handheld device use and image upload.
Change service sites	Site 4	In response to low scanning numbers and tensions at the main facility between the local community members and the participating facility, in February 2024 additional staff were trained at a new facility in Site 4, which serviced the surrounding homelands (small satellite communities).	Staff training	At study completion, the scanner closest to finishing training was a GP at the additional facility. Observational data also suggested that this facility offered an environment more conducive to training.
Change equipment	Sites 2, 3, 4	Initially image upload was reliant on facility WiFi, but dongles were delivered to some sites in mid-2024 due to consistent WiFi issues.	Image upload	There was some evidence that the delivery of dongles contributed to improved image upload capacity, with one participant noting "It's there as a backup" [GP4]. However, issues with the dongles, such as unreliable charging and missing devices, were also reported: "I have had more problems with the dongle being flat" [FGGPO] and "the dongle does not hold charge and turns itself off... now it is just turning off at random therefore no internet" [OFN2]. These observations suggest partial resolution of connectivity challenges, with remaining limitations reflecting an implementation shortfall.
Conduct ongoing training (including shadowing experts)	All sites	More training than initially planned was required at all sites in response to reported skill and confidence decline after periods without scanning. Accordingly, cardiac sonographers made frequent visits throughout the study period to provide ongoing training.	Staff training and SPLASH protocol	Ongoing training appeared to strengthen staff skills and improve scan quality. The odds of a scanner performing at least one scan were 18 times higher on days when an expert was present compared with days when no expert was present (OR = 18.15, 95% CI 10.87–30.26, $p < 0.001$). Staff described these visits as valuable for sustaining motivation and confidence; for example, one scanner noted that it "definitely helped with [the cardiac sonographer] coming out to [Site 4] twice now, just for two days or so, it lifts up confidence and gets the momentum going again." [FGGP4]
Develop and distribute promotional material	All sites	Locally tailored posters were developed and displayed across various sites to promote specific screening events.	Staff training	These materials may have contributed to community awareness of screening activities, although this was not assessed in this evaluation.

Table continued from previous page

Implementation strategy*	**Sites**	**Activities delivered (including adaptations)**	**Programme components**	**Evidence of contribution to programme component or shortfalls**
Develop education materials	All sites	Using feedback from the training conducted at these sites, a training course was developed to be accredited with the Australasian Society for Ultrasound in Medicine. This course was in the final stages of development at the time of writing and is due to launch in 2026.	Staff training	This strategy was not delivered in time to influence the NEARER SCAN programme but will be used in future training.
Identify and prepare champions	Sites 1 & 5	An individual at Site 1 championed the programme during the implementation design and early implementation period by engaging community stakeholders, promoting it through internal newsletters and reports, and organising local graduation events. After a promotion in 2024, their capacity to continue this role decreased. At Site 5, a GP scanner later took on a similar role, coordinating with managers to encourage scanning and raising it at morning meetings.	Cross-cutting	At Site 1, it was observed that the site champions "holds a key position for NEARER SCAN as someone with true connection with local community residents" [OFN1]. The informal champion who emerged at Site 5 commented "probably has been my influence a bit as well and the other GPs, to make it a full clinic response" [GP5].
Make training dynamic	Site 4	The February 2024 training at Site 4 was adapted to reflect local learning preferences, prioritising experiential approaches such as early hands-on scanning opportunities and peer observation. Aspects of the training were delivered in trainees' first language, incorporated storytelling, and facilitated group discussions on clinical topics.	Staff training	Observational data suggest these adaptations contributed to effective initial training at the second Site 4 facility. "Trainees freely asked questions in the group sessions," which was interpreted as "providing evidence that the training approach was effective for this group" [SR4]. "Most trainees achieved over 20 scans during the week, with one gaining 35" [SR4]. Engagement extended beyond the facility setting: "Many initiated bringing their family members for scans." Additionally, outreach sessions "were undertaken over one afternoon in neutral public locations," which were "selected by the trainees, who constantly monitored the social dynamics of these sites and directed when the scanning should cease" [SR4]. However, those trained did not go on to complete 100 scans.
Remind clinicians	Sites 2 & 5	Sites 2 & 5 developed a recall notification within their clinical information system.	Staff training	Qualitative data suggest that recall systems contributed to the number of scans performed. A GP at Site 5 commented, "We have a recall in [our computer system]. We have a NEARER SCAN recall, 'Has had a scan,' 'Is it reported?' it highlights red. That has worked with our antenatal patients because the midwives have put that recall on and ticked those boxes" [GP5]. Similarly, another scanner noted "clinic recalls [have helped]. There is a template in our software, the organisation is expecting us to do it" [FGGPO(2)].

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Implementation strategy*	Sites	Activities delivered (including adaptations)	Programme components	Evidence of contribution to programme component or shortfalls
Screening events	Sites 1, 2, 3	Screening events were coordinated in partnership with facilities, including delivery at schools or community venues.	Community engagement and staff training	Site 3 held regular screening events, and on event days averaged 8.6 scans per scanner per day compared with 0.1 scans per day on non-event days. Screening events were commonly described as a helpful strategy for creating protected time to complete scans: "The scheduled events are much easier for us, it frees up a bit of time" [N3(2)].
Visit other sites	Sites 2 & 4	Facilitated opportunities for scanners to join a regional mass-screening week with expert cardiologists and sonographers.	Staff training	Informal feedback from scanners who joined trip spoke to the benefit of the opportunity.

*Strategies as per those identified in the implementation design (Chapter 4) and using Powell et al.'s typology[188]. The number following each cadre designation (e.g. FNCHW5, GP3) indicates the site from which the data were collected. References prefixed with 'FG' denote focus group data. References prefixed with 'OFN' denote observational field note data. All others quotes are drawn from interviews. CM = clinic manager, N = nurse, FNCHW = First Nations community health worker, OFN = observational field note, SR = site report, GP = general practitioner.

D.3 NoMAD survey results

Mean NoMAD domain scores

Site	Coher. early	Coher. late	Cog. partic. early	Cog. partic. late	Collect. action early	Collect. action late	Reflex. mon. early	Reflex. mon. late
1	4.4 (0.4)	3.8 (0.5)	4.6 (0.4)	4.2 (0.1)	4.2 (0.4)	4.2 (0.3)	4.2 (0.5)	4.4 (0.6)
2	4.3 (0.1)	4.2 (0.8)	4.8 (0.2)	4.3 (0.6)	3.9 (0.5)	4.1 (0.7)	4.3 (0.1)	4.1 (0.8)
3	4.3 (0.7)	4.6 (0.2)	4.6 (0.4)	4.3 (0)	4.3 (0.4)	3.8 (0.1)	4.0 (0.6)	4.0 (0)
4	3.8 (0)	3.8 (0.3)	4.3 (0.7)	3.7 (0.4)	3.4 (0.4)	3.4 (0.8)	3.6 (0.3)	3.2 (0.9)
5	3.8 (0.2)	4.5 (NA)	4.0 (0.5)	4.5 (NA)	3.4 (0.1)	4.3 (NA)	3.8 (0.4)	4.2 (NA)
Card.	NA	4.1 (0.7)	NA	4.5 (0.4)	NA	3.8 (0.3)	NA	3.7 (0.5)
Total	4.2 (0.5)	4.1 (0.6)	4.5 (0.5)	4.2 (0.5)	4.0 (0.5)	3.9 (0.6)	4.0 (0.5)	3.9 (0.7)

Mean NoMAD domain scores, with standard deviation in parentheses, for early and late implementation phases across sites. Column headings are abbreviated. Colour shading indicates level of agreement based on the mean score: 3.00–3.49 = terracotta , 3.50–3.99 = orange, 4.00–4.49 = green, 4.50–5.00 = blue green. Cohere. = coherence, Cog. partic. = cognitive participation, Collect. action = collective action, Reflex. mon. = reflexive monitoring, NA = not able to be assessed, Card. = cardiologist.

E

Appendices for realist evaluation

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E.1 Evolution of realist evaluation

This appendix provides a transparent account of how the realist evaluation research questions, design, and programme theory evolved. It illustrates the iterative refinement that guided data collection and analysis, allowing the evaluation to remain responsive to emerging evidence and context-specific insights, consistent with realist evaluation principles[124].

The initial and final versions of the programme theory, as well as the final evaluation design and research questions, are presented in Chapters 6. This appendix focuses on documenting the refinements that occurred between these stages.

Research questions evolution

The table below summarises how the realist evaluation questions evolved and the rationale for each refinement.

Evolution of realist evaluation questions

Evaluation phase	Research question	Rationale for refinement
Start of evaluation	What works when integrating a task-sharing RHD screening programme into routine service delivery in remote Australia, under what circumstances, and why?	Broad framing at this initial stage, reflecting an exploratory intent to identify key contextual influences and mechanisms shaping implementation. The emphasis on task-sharing recognised it as a pivotal but under-examined feature of the programme's integration.
Phase 1	How, why, for whom, and under what circumstances can task-sharing programmes that introduce a completely **new** task to a health facility be integrated into routine delivery?	Refined to achieve a more appropriate level of abstraction based on emerging explanatory insights. The focus shifted from a specific programme to a broader sub-type of task-sharing interventions involving the introduction of a new task within a service.

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Evaluation phase	Research question(s)	Rationale for refinement
Phase 2	How, why, for whom, and under what circumstances can task-sharing programmes that introduce a completely new task to a health facility be integrated into the routine work of **First Nations community health workers** in remote Australia.	Refocused to re-engage with the empirical setting and examine how contextual and relational mechanisms operated among First Nations community health workers. This adjustment reflected the richness of data emerging from these contexts.
Phase 3	How, why, for whom, **to what extent**, and in what circumstances can **handheld screening echocardiography** be **embedded** into the routine work of First Nations community health workers in remote Australia.	Final refinement aligned the question with the explanatory scope of the emerging programme theory. The inclusion of "to what extent" reflected integration of quantitative data to assess variation across sites. The shift to "handheld screening echocardiography" reflected the apporpriate abstraction level and "embedded" the phase of normalisation that was being examined.

Evaluation design evolution

The study design evolved iteratively in response to emerging findings and the developing programme theory, with several key refinements made across phases. During Phase 1, it became apparent that interviewing programme participants could help explain factors influencing embedding from the perspective of those being offered scans. Although these interviews were planned for Phase 2, logistical constraints prevented their inclusion. This omission is discussed further in the Chapter 6 limitations. Interviews and surveys with cardiologists reviewing echocardiographic images were added in Phase 2 to capture their perspectives on how the remote review process contributed to programme integration. Analysis of NoMAD surveys was deferred to Phase 3 after additional data were collected in Phase 2, as surveys from Phase 1 alone provided limited explanatory insight. Finally, the original plan to conduct formal focus groups in Phase 3 for theory consolidation was revised. Given the maturity of the emerging programme theory and the extent of ongoing engagement with participating sites, informal sense-checking discussions were deemed sufficient to confirm explanatory coherence.

Programme theory evolution

Draft programme theory 1

The first draft of the programme theory was developed at the conclusion of Phase 1 of the empirical testing process. This phase of data collection and analysis generated 45 CMOcs, with 34 newly developed and 11 refined from the initial programme theory, which together informed the first draft of the realist programme theory.

The evaluation at this stage suggests three preliminary factors that appear to influence the integration of the task within routine practice. First, the extent to which scanning becomes embedded within the FNCHW's role. Second, the degree to which scanning is institutionalised as a normal activity within the health facility. Third, the extent to which the burden of scanning is reduced.

1. Embedding scanning as a task within the community health worker's role

Several aspects of role theory appear relevant to how FNCHWs engage with the scanning task. Role ambiguity arises when FNCHWs are uncertain whether scanning is expected of them by other staff members, which can create hesitation to adopt the task. However, when an FNCHW is asked to perform a scan by an authority figure, such as a manager or visiting clinician, this interaction provides clarity that scanning is an expected part of their role, thereby reducing ambiguity (CMOC 1.1). Framing this request as an opportunity rather than an obligation also appears to foster engagement with the role rather than feelings of coercion (CMOC 1.2). In essence, the request functions as a form of role endorsement, reinforcing that scanning is not merely permitted but expected within the facility's service delivery. With repeated legitimisation of the task, scanning may become internalised within the FNCHW's role identity, and eventually embedded as part of their everyday work (CMOC 1.3, 1.4).

Similarly, visiting implementation team members also appear to influence programme implementation. Visiting team members can act as socialising agents, reinforcing to both the FNCHW and other staff that scanning is now a normative task within the FNCHW's clinical role (CMOC 1.4, 1.5). In this sense, the nudge functions as a cue, increasing the salience of the role for the FNCHW (CMOC 1.6). Greater role salience enhances the readiness to act out that identity, supporting continued engagement with scanning. In addition, the presence of visiting cardiac sonographers provides more than just technical support; it serves as a symbolic resource for the FNCHWs. Through relational identification, FNCHWs align their professional identity more closely with that of the sonographers, which again increases role salience and the likelihood of scanning (CMOC 1.13).

Role ambiguity among FNCHWs can also be alleviated by clinic managers through how they position the scanning task. For example, managers can validate that scanning falls within the FNCHW's role boundaries by providing public recognition, which serves as a form of role legitimation (CMOC 1.8). When managers emphasise the skilled nature of the task, it sends a strong symbolic message to other staff and functions as role reinforcement (CMOC 1.17). In this sense, the way managers communicate about the programme is not merely logistical but can shape role identity for FNCHWs. Other staff members who are not trained in scanning can also contribute to this process. For instance, social reinforcement from trusted peers such as nurses or GPs can strengthen confidence in role performance. In this way, peer support acts as a role-affirming mechanism, increasing both role clarity and psychological safety for FNCHWs.

2. Institutionalising scanning as a normal activity within the health service

One element that appears to influence this factor is the expectation of patients. The data collected so far suggest there is limited coherence when scans are offered at times when the patient is acutely unwell (CMOC 1.25). An exception is nurses working in acute care, who perform scans on patients presenting with symptoms suggestive of ARF or RHD, as this aligns with their immediate clinical workflow, even though it represents a deviation from the original intention of the programme. In contrast, when scanning is offered during a routine health check, particularly by a GP, it aligns more closely with the purpose of the visit and therefore feels like a normal and expected part of care (CMOC 1.27). This aspect of the programme theory will be further examined in the next phase through interviews with patients.

The data suggest a dominant preference for scanning to occur during scheduled activities rather than opportunistically (CMOC 1.24). This finding represents a deviation from the initial programme theory. Structured time allocation by managers appears to help staff make sense of how scanning fits within the broader model of health service delivery. It positions scanning as a sanctioned, and at times protected, component of service delivery, which in turn promotes a shared understanding of the task's purpose and value within the facility. This mechanism also relates to cognitive participation; when staff observe managers valuing scanning enough to protect time for it, they may be more inclined to learn about the programme and contribute, for example by referring patients to FNCHWs for scanning.

The visibility of scanning within the facility appears to play an important role in shaping perceptions of the programme as a normal part of routine care (CMOC 1.29). When scanning is not visible to the broader staff team, they are more likely to view the programme as external to their core business and therefore less inclined to make changes to integrate it into routine practice. In these circumstances, scanning may be perceived as an isolated research activity understood by only a few staff members, rather than a legitimate and established component of service delivery. Without these visible cues, it becomes more difficult for staff to make sense of the programme as something that is collectively owned and routinely performed within the facility.

The presence and involvement of an external research team appear to influence how the programme becomes integrated (CMOC 1.30). When clinic managers are familiar with research teams leading similar initiatives, this familiarity may reduce their sense of local responsibility for institutionalising scanning as part of routine practice. In such cases, managers may defer authority, decision making, and accountability to the research team, which in turn reduces opportunities for local, facility-led problem solving. This pattern reflects a disruption in cognitive participation among key actors, particularly clinic managers, who play a central role in driving the introduction of new tasks. Without a deliberate handover of responsibility to local teams, the programme risks remaining overly dependent on the research team, which poses challenges for sustainability.

Institutionalising scanning as a routine activity appears to depend strongly on the leadership dynamics within the facility. Consistent and visible support from managers helps build staff confidence in the programme's legitimacy (CMOC 1.31, 1.32). Importantly, it is active support rather than passive or symbolic endorsement that fosters this confidence. At one facility, informal leaders who might otherwise have been able to exert their influence to support the programme were constrained by a lack of respect from formal management. This highlights the importance of alignment between formal and informal leadership in sustaining collective commitment to the programme.

3. Reducing the burden to scan

Small, cumulative practical adjustments appear to make scanning feel easier to integrate within daily workflows. For example, access to safe and secure storage locations with the ability to charge devices makes scanning easier to perform than to avoid, thereby increasing the likelihood that it is enacted. These low-friction modifications influence the everyday cost–benefit judgements that FNCHWs make when deciding which tasks to prioritise.

The task of scanning also involves several ancillary, technology-related steps. When these steps are completed seamlessly, they remain largely invisible, but when problems arise, they can substantially increase the perceived burden for FNCHWs. For example, delays in uploading scans (CMOC 1.37, 1.38, 1.43), a lack of clarity regarding whether images have been reviewed (CMOC 1.42), or inaccessible avenues for technical support (CMOC 1.40, 1.41, 1.44) all contribute to administrative friction that reduces the likelihood of scanning. This occurs because the task begins to lose procedural predictability. If FNCHWs must manage additional emotional labour each time they intend to scan, they are more likely to disengage from the activity.

Introducing the task of scanning also introduces an additional cognitive load. FNCHWs must decide when to scan, recall their training, and manage uncertainty about their performance. When scanning occurs infrequently, confidence appears to wane, requiring greater cognitive effort to complete the task (CMOC 1.45).

Draft programme theory 2

The second draft of the programme theory was developed following Phase 2 of the empirical testing process. This phase generated a substantially expanded set of CMOcs, increasing from 45 in Phase 1 to 118. This expansion reflects the more detailed and differentiated understanding gained through continued data collection and analysis, where subanalyses were unpacked into finer-grained explanatory propositions. In realist terms, this process represents the elaboration of causal pathways and mechanisms to better capture the variation observed across contexts. In this phase the theory began to be organised around the ten hypothetical questions that later framed the final CMOC list.

In this section, only one component of the draft programme theory, the process of requesting a scan, is presented for brevity.

At its most fundamental level, a request for an FNCHW to perform a scan can legitimise scanning as part of their role and provide assurance to scan on that occasion (CMOC 2.1). Bringing the task of scanning within the perceived role boundaries of FNCHWs is an important step in its integration into routine practice. In facilities where GPs were trained alongside FNCHWs and nurses, staff often defaulted to requesting the GP to scan, reflecting an anchoring to prior expectations that diagnostic tasks are typically performed by doctors (CMOC 2.2).

Multiple considerations appear to shape the decision to ask an FNCHW to scan. In facilities where staff expressed high levels of trust in the clinical abilities of FNCHWs, they were more confident in their capacity to scan and were therefore more likely to make such requests (CMOC 2.3). This did not apply across all Aboriginal Health Practitioners, who generally have greater formal clinical training, suggesting that the mechanism operates more through trust built over time than through trust based on qualifications.

The nature of the request itself also appears to influence integration. When doctors with long-term relationships in the community request FNCHWs to scan, the relational trust built over time makes it more likely that the FNCHW will perform the scan (CMOC 2.4). Moreover, when requests are framed as opportunities rather than obligations, the autonomy afforded may enhance engagement with the programme over time (CMOC 2.5). Visibility of scanning within the facility is another important factor that generates requests; when scanning is visibly and consistently performed, it becomes an expected practice, and FNCHWs are more likely to be asked to scan by their colleagues (CMOC 2.6).

Repetition of requests also appears to support the embedding of the programme. Repeated requests may help FNCHWs internalise the identity of a scanner through the cumulative legitimisation that comes from being asked to perform the task (CMOC 2.7). However, if such requests occur too frequently, they can have unintended consequences. For example, if FNCHWs only scan when explicitly asked, they may come to perceive scanning as conditionally legitimate, i.e. something appropriate only when directed, rather than an activity they can initiate independently (CMOC 2.8).

E.2 VICTORE complexity

Volition: In remote communities, the small population size and communal way of being mean that health facilities are closely intertwined with the community and may be more responsive to its views. Accordingly, health facility actors' volitions may be influenced by the broader community opinion during programme implementation. These communities are also overburdened with new programmes[317], some of which succeed only while being researched and falter once the research team departs. This raises the question of whether actors will be motivated to implement the screening programme if it is not seen as sustainable beyond the study period. Finally, as a new and unproven programme, implementation depends largely on actors (a) holding a strong belief in its potential to make a difference, which is difficult to convey at an early stage. It also relies on (b) a strong desire to acquire and practise the new skill, despite the initial absence of financial incentives or credentialing that may later emerge if the programme proves successful.

Implementation: The implementation chain for this programme is outlined in the Theory of Change diagrams (Chapter 4). While it varies slightly across sites depending on the design outcomes, a typical participant journey involves: attending a clinic or designated screening event for screening; if positive, referral for a diagnostic echocardiogram at the nearest tertiary centre; if diagnosed with RHD, prescription of appropriate management (e.g. secondary prophylaxis) by the local GP; and subsequent monitoring through regular echocardiograms. This process involves multiple actors, including health service managers introducing the programme, local scanners acquiring images, experts reviewing them, tertiary hospital staff conducting diagnostic echocardiograms, local GPs prescribing management, and finally the local scanners conducting follow-up scans.

Context: (i) Individuals eligible for screening are those who will attend the health facility or designated screening events; consequently, the programme will not reach those who do not attend. Scanners will typically be FNCHWs who are from, or have long-standing ties to, the community. Expert reviewers will initially be those directly involved in, or adjacent to, the programme, although over time may extend to cardiologists who have had little prior involvement in RHD work. (ii) Several key interpersonal relationships underpin implementation. The task-sharing relationship between scanners and experts may depend on open feedback channels, while communication among the referring clinician, local clinic, and diagnostic imaging centre will be critical to ensure that participants with positive screens receive follow-up echocardiograms. (iii) Participating sites include ACCHOs and government clinics, each differing in their degree of connection with the local community and capacity to implement the programme. (iv) Broader infrastructure considerations include the socio-cultural history of First Nations Australians, limited RHD funding, cultural diversity among communities, and the level of governmental commitment to addressing RHD.

Time: Recent shifts in RHD funding in Australia have altered the implementation landscape. In 2022, the Australian Government announced new funding for NACCHO to lead national RHD efforts, signalling a broader transition from research-focused work toward community-led implementation approaches[81]. This project sits somewhat between these approaches, as an implementation-focused research initiative designed to generate evidence while supporting practical delivery within services. As a new initiative, it may also be susceptible to the 'showcasing effect', where initial enthusiasm fades as implementation progresses. Furthermore, as explored in the Rivalry section, numerous RHD and technology-driven programmes have previously been introduced in some of these communities, and their varying successes or failures may shape how this programme is perceived.

Outcomes: An important consideration for this programme will be which outcome measures government stakeholders will prioritise in determining whether to scale up the programme. Likewise, it will be important to consider what the community will view as a successful programme. Managing these potentially divergent perspectives may be challenging.

Rivalry: Some communities involved in this programme may feel over-researched. For example, the Northern Territory implemented a moratorium on research during COVID-19, which remains in place in some communities even at the outset of this study. Several recent and ongoing RHD initiatives co-exist, including an outreach-to-household programme with Aboriginal Health Workers[227,318]; a penicillin reminder programme based on the full moon cycle[319]; the On Track Watch training and certification programme[320]; and the Champions4Change programme[321]. Broader efforts include the Northern Territory RHD Control Programme, RHD register, Northern Territory Government RHD programme, END GAME Centre for Research Excellence, clinical management guidelines, and the END RHD Strategy[76]. Beyond RHD, multiple technologies, such as telehealth, e-health registers, and remote monitoring, are also being introduced, some through horizontal system strengthening and others as part of vertical programmes targeting specific conditions.

Emergence: Potential long-term effects of this programme include the deskilling of scanners if screening volumes remain low within individual communities. Future adaptations could include formal credentialing and remuneration to support skill retention. As the programme spreads, neighbouring communities may seek to implement it locally or access screening through nearby sites rather than travelling to tertiary centres. Given the high staff turnover in remote clinics, developing strategies to maintain scanning skills will be critical in each setting.

E.3 Substantive theories informing initial programme theory

The following substantive theories informed the development of the initial programme theory:

- **Normalization process theory:** Explains how new practices become routinely embedded within healthcare systems[138].
- **Kotter's 8-step change model:** Describes eight sequential stages for implementing and sustaining organisational change[219].
- **Self-determination theory:** Focuses on intrinsic motivation and the role of autonomy, competence, and relatedness in driving behaviour[220].
- **Structuration theory:** Examines how social structures shape and are shaped by individual agency in practice[221].
- **Coloniality of power theory:** Highlights how colonial power relations continue to structure knowledge, institutions, and health systems[222].
- **NASSS framework:** Identifies factors influencing the adoption, spread, and sustainability of healthcare technologies[192].
- **Psychological safety theory:** Emphasises the importance of creating environments where individuals feel safe to take interpersonal risks and learn[226].
- **Ebbinghaus forgetting curve:** Describes the exponential decline of memory retention over time and the benefits of spaced retraining[229].
- **Self-efficacy theory:** Explores how belief in one's ability to perform specific tasks influences motivation and performance[230].

- **Diffusion of innovations theory:** Explains how innovations spread through populations and the factors affecting adoption[93].
- **Schema theory:** Examines how cognitive frameworks influence perception, interpretation, and learning[233].
- **Priming theory:** Suggests that prior exposure to stimuli can influence subsequent perceptions, decisions, or behaviours[234].
- **COM-B model:** Proposes that behaviour results from the interaction of Capability, Opportunity, and Motivation[235].
- **Cognitive load theory:** Describes how excessive mental effort impairs learning and performance, emphasising optimal information design[236].
- **Experiential learning theory:** Describes how people learn best by doing, reflecting on their experiences, and then trying out new approaches[237].
- **Job characteristics theory:** Explores how task variety, autonomy, and feedback influence employee motivation and satisfaction[238].

E.4 Existing evidence informing initial programme theory

Data extracted from existing evidence

Source	Programme type (realist)/document (non-realist)	Context (C), Mechanism (M), Outcome (O), Other
Uptake of a primary care atrial fibrillation screening program (AF–SMART): a realist evaluation of implementation in metropolitan and rural general practice[322]	Screening programme	• In some practices, undertaking intensive screening over a shorter period (e.g. during annual flu vaccination) worked well, provided sufficient staff time was allocated and clear follow-up protocols were in place (C). • Practice-wide engagement driven by senior GP leadership and regular QI feedback caused internal competition between GPs and nurses (M).
Task shifting to improve the provision of integrated chronic care: realist evaluation of a lay health worker intervention in rural South Africa[240]	Task shifting programme	• Both patients and nurses believed that the reminders (C) encouraged (M) patients to adhere to their appointment dates (O). • A well-managed clinic proved an ideal environment for task shifting (C). • Managers were flexible, consultative, and willing to act on suggestions, sometimes from junior staff and patients (C). • Reliable supply and maintenance of necessary equipment (C). • Tension among staff (C).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Substance misuse intervention research in remote Indigenous Australian communities since the NHMRC 'Roadmap'[323]	Rural / First Nations health programme	• Home environments and local relationships exerted strong influences that interventions struggled to change, even with Indigenous health workers and face-to-face counselling (C). • Local Indigenous health workers (C) augment and sustain effects by engendering social and cultural resources (M), increasing trust in medical authority (O). • Motivated to abstain (O). • Community-wide suites of evidence-based interventions (C) shift attitudes and create favourable environments for cessation (O). • Locally relevant data (C) stimulates or supports local agency to act (O). • Community-owned diversionary strategies reduce youth binge drinking (C) by providing valued alternatives (M), increasing desire to participate over desire to consume (O).
A realist review of mobile phone-based health interventions for non-communicable disease management in sub-Saharan Africa[324]	Rural health programme	• The reviewed studies revealed that a positive attitude toward the mobile technology and the ability to communicate in a common language were the most important predisposing characteristics (C), contributing to the perception that mHealth was useful and easy to use (O). • The needs of patients and providers, such as a high perceived burden of disease e.g. in cases of reduced mobility) and the perceived lack of capacity of first-contact providers to provide adequate care (C), influenced the perceived usefulness and ease of use (O). • Availability of a stable communications network, accessible maintenance services, and regulatory policies e.g. on data protection) (C), contribute to the perception of patients and providers that mHealth interventions are useful and easy to use (O).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Use of clinical guidelines in remote Australia: A realist evaluation[325]	Rural health programme	• Acceptance of the worth of the protocols to their clinical practice, reliance on manual content to guide their practice, the perception of credibility, and applicability of RPHCM content to the context, as well as a compulsion, imposed by the organisational policies, for them to use the manuals (M). • Relevance of the protocols to the remote context and a lack of alternative resources to guide remote clinical practice (C). • While the manuals were widely accepted in remote clinical practice, official endorsement of the manuals, especially the CARPA STM and WBM (C), also compelled remote health practitioners (M) to actively use the manuals (O). • Further, the hard copies continue to be the preferred version for use in remote clinics even with the advent and availability of the electronic (html) version. The need for hard copy publication will continue into the foreseeable future because of the overwhelming support for them from the evaluation participants (C). • Comments about format and layout are also being actively considered. Important feedback from the interviews was the barrier that registration and user login created for efficient access to the online manual content (C). • Providing patients with personally relevant information that addresses their concerns and expectations was important for them (C), to accept and follow safety-netting advice (O) as personalising information increased relevance and usefulness (M).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
A realist evaluation of a community of practice for dietitians and nutritionists working in Aboriginal and Torres Strait Islander health[326]	First Nations health programme	• When participants recognise that working in Aboriginal and Torres Strait Islander health requires multiple ways of being and working (C), the community of practice fosters relationships that form the foundation of an empathetic environment (M), to navigate the various tasks of becoming a more responsive health professional working in Aboriginal and Torres Strait Islander Health (O). • When participants who are committed and open to improving their practice in Aboriginal and Torres Strait Islander health (C), and take part in the community of practice, they feel supported and guided to be reflexive by facilitators (M), becoming self-aware, insightful, and more confident in themselves (O). • When skilled facilitators work with committed participants with varied experience and roles (C), the sharing, reflexivity, feedback and support offered (M), shifts consciousness to their own practice to be able to manoeuvre in intercultural spaces and advocate through speaking 'with and not for' (O). • Where participants with varied experience and roles share the lived experience of working in Aboriginal and Torres Strait Islander health (C), the community of practice promotes connection through feelings of understanding and being understood through sharing, feedback and support (M), which contributes to their commitment to remain working in Aboriginal and Torres Strait Islander health (O). • When participants with varied experience and roles (C) share, feedback, support, and collaborate in the community of practice, they can see the value of and gain confidence in new perspectives, skills and practices (M), which they take back to their communities, workplaces, colleagues and students, and integrate into their practice (O).

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Source	**Type/document**	**Context (C), Mechanism (M), Outcome (O), Other**
Screening for rheumatic heart disease[327]	News article	• Refining of handheld echocardiogram equipment (C), is vital in helping launch nationwide screening programs in poor and resource-strapped countries (O). • Much work is going on to modify the current WHF norms for use with handheld machines. This has to include the risks of over detection of RHD, the reduced sensitivity due to the use of oversimplified criteria, and the unnecessary anxiety and trouble caused to a patient wrongly diagnosed with RHD (Other). • Detecting and treating adults as a priority, may be far more impressive in terms of cost-effective prevention of symptomatic RHD than screening of children (Other).
Rheumatic heart disease screening: current concepts and challenges[328]	Journal article	• It has been suggested that screening older age groups to include young adults and pregnant woman (C), would increase pick-up rates of RHD and improve echocardiographic detection of disease (O). • Screening school children, comes at a price as school attendance in poor areas can be <0.70, risking underestimating the prevalence of disease in those most likely to be worst affected (Other). • The decisions regarding how and where limited resources should be focused in developing countries is an important ethical question and the decision regarding whether to invest in echocardiographic RHD screening programs at the expense of other, possibly more robust evidence-based interventions for other conditions, warrants due consideration (Other). • The decisions regarding how and where limited resources should be focused in developing countries is an important ethical question and the decision regarding whether to invest in echocardiographic RHD screening programs at the expense of other, possibly more robust evidence-based interventions for other conditions, warrants due consideration. A cheaper alternative (and which may reach a wider audience) is web-based learning that is open to everyone (Other).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Focused cardiac ultrasound screening for rheumatic heart disease by briefly trained health workers: a study of diagnostic accuracy[53]	Journal article	• FoCUS screening test performed by nurses who had completed a brief, structured training programme (C), was accurate for the diagnosis of RHD (O). • Large number of skilled workers, which would not be feasible in many settings. To our knowledge, New Caledonia, Tonga, and Samoa, are the only countries to have implemented public-health screening programmes for RHD using echocardiography. All have populations of less than 300000 people and the most populous of these, New Caledonia, has a substantially greater physician workforce capacity than do most settings with a high prevalence of RHD (Other).
Determining the risk of developing rheumatic heart disease following a negative screening echocardiogram[329]	Journal article	• Children with prior negative screen are unlikely to develop severe disease over a 3–7 year timeframe (Other). • While this study was not designed to understand this difference, it is possible that multiple prior echo screening studies, which included RHD education in schools, health centers, and in the community (C), may have increased awareness (M), and subsequently reduced community rates of new RHD through improved primary and secondary prevention (O).
Rheumatic heart disease echocardiographic screening: approaching practical and affordable solutions[330]	Journal article	• The program improved health awareness, facilitated engagement between the community and local health service, and raised the profile of ARF/RHD in the community (O).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Patient and health-care impact of a pilot rheumatic heart disease screening program[331]	Journal article	• Although potentially abnormal screening echocardiograms did generate an initial health service response (C), this did not necessarily result in a face-to-face clinical review (O). This may in part be explained by, the lack of carer recall of the echocardiogram findings despite documented contact by the local primary health-care service (M). • Although the earlier RHD screening study occurred in consultation with primary and specialist health-care providers, there was no provision on the part of the study or the local health service to allocate additional resources to facilitate clinical follow-up (C). It is therefore not surprising that the majority of health-care providers surveyed identified at least some impact on their local health-care service. The fact that 30% of those surveyed who were involved in this follow-up felt this impact was substantial (O). • School-based echocardiographic screening programme in New Zealand (C), well received with no reported negative effects by parents of children with both normal and abnormal scan results. All participating families showed support to participate in any future screening programmes (O). • Clinicians surveyed in Wark et al. study voiced concerns about the diagnostic uncertainty and resulting dilemma when counselling parents and families (C).
Family acceptability of school-based echocardiographic screening for rheumatic heart disease in a high-risk population in New Zealand[332]	Journal article	• In our study, we judged that it was important that the child and parents were seen by a specialist to provide a full and accurate clinical explanation of the scan result and advice on subsequent management (C), which would have been difficult and inappropriate to convey via phone (M). • This survey thus reinforced that the time from notification of an abnormal test until counselling about the test result should be kept as short as is practically possible (C).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Handheld echocardiographic screening for rheumatic heart disease by non-experts[55]	Journal article	• Individualised evaluation and training schedules, with feedback (C). • Technical issues similar to those previously reported, including 'freezing' of the HAND device with overheating and short battery life. Despite proactive steps, such as multiple devices per nurse and docking the device between usages, there were still multiple technical delays. As HAND technology evolves, such difficulties may decrease (C).
Effectiveness of systematic echocardiographic screening for rheumatic heart disease in nepalese schoolchildren: a cluster randomized clinical trial[333]	Journal article	• Longer term SAP had better outcomes (Other). • School-based screening was pragmatic (C).
Contemporary issues in rheumatic fever and chronic rheumatic heart disease[334]	Opinion piece	• Miss adults. In the study from Nicaragua, the prevalence of echocardiographically detected RHD in adults aged 20 to 35 years, although lower than children, was still significant at 22/1000. These data would suggest that a screening strategy confined to school children only may be insufficient to identify the true prevalence of RHD (Other).
Screening for subclinical rheumatic heart disease: addressing borderline disease in a real-world setting[335]	Journal article	• There is a concern that the borderline group comprises a heterogeneous group of predominantly non-RHD individuals. This has important implications for the feasibility of an RHD control programme where the number of screened individuals requiring detailed scans and long-term follow-up has the potential to considerably increase the total screening cost (Other).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Echocardiographic screening for rheumatic heart disease[336]	Textbook chapter	• Given the complexity of the information, and uncertainty surrounding the accuracy of the test and the effectiveness of the intervention, the use of decision aids may be helpful (C). • A New Zealand study found that prescreening education, in the context of a major public health initiative, contributed to high levels of awareness around sore throat and ARF (Other). • A Ugandan study found that the screening activity was well accepted by teachers and school students, but identified opportunities to improve prescreening education (Other). • As screening is only properly established as a program in one country at present (New Caledonia, population 280,000), there is limited evidence to assess these criteria, although experiences of research activities (which are generally more highly resourced than health programs) provide some insights (Other). • For example, Roberts[30] described difficulties with enrollment, consent, and timely and appropriate follow-up following RHD screening in Australia (C). • Challenges of community engagement, consent, participation, follow-up, and workforce restrictions for nonexpert operators were reported in Brazil. It is evident the human, infrastructure, and financial resources required for testing, diagnosis, follow-up, monitoring, and quality assurance will be considerable, and are likely to be a major challenge in resource-limited settings (C). • However, while a negative screening result seems to have no negative impact a positive result has been shown to cause increased anxiety, decreased physical activity, and decreased parental and child quality of life (Other). • Strong support for RHD screening has been voiced by parents of screened children in New Zealand and screened children and their teachers in Uganda (Other). • School screening may not be appropriate in areas where school enrollment and attendance are lower (C).

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Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
The impact of a peer support group for children with rheumatic heart disease in Uganda[337]	Journal article	• Peer support groups (C), minimize the negative psychosocial effects associated with early RHD detection (O). • Adherence to monthly injections is challenging, and recent cohorts of RHD patients have reported only slightly more than half receiving an adequate number to confer protection. By improving social connectedness, support groups could play a critical role in improving adherence. Further work is needed to study this effect directly, as our cohort had uniquely high baseline adherence (Other).
Prevalence of rheumatic heart disease detected by echocardio-graphic screening[29]	Journal article	• Charitable organisations fund equipment (Other). • New-generation echocardiographic equipmentallows a high volume of examinations to be performed in a short time, thanks to increasingly faster and better performing software (C).
Echocardiographic screening for rheumatic heart disease in a Ugandan orphanage: feasibility and outcomes[338]	Journal article	• An additional factor in favor of running screening programs "on site" (in villages or, as in this case, in a community) (C), is the increased adherence of the subjects (in our study, 100% of the children living in the orphanage and about 50 children who came by word of mouth). (O). • This finding, relevant in all communities, is even more common in a developing country where travel is often long and complex and accompanying a child to the hospital means lost time and income for a family member (Other) • While limiting the generalization of these results to other situations (e.g. small villages far from population centers and with low socioeconomic and/or cultural status) (C), in these regions word of mouth is very effective, being a valid instrument (M), to recruit volunteers and, albeit with difficulty, logistical obstacles can likely be overcome (O).
Paths to improved rheumatic heart disease: screening and prophylaxis[339]	Journal article	• Moreover, the technique has a further benefit (C), in that it allows for by not requiring the removal of garments for effective usage, which is particularly beneficial in school screening programmes (M), therefore greater privacy for patients (O).

Table continued from previous page

Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Challenges for the Implementation of the First Large-Scale Rheumatic Heart Disease Screening Program in Brazil: The PROVAR Study Experience[340]	Journal article	• Prior to screening, an educational curriculum was implemented, including lectures and printed material, for students and their parents, teachers and school staff regarding the importance of streptococcal pharyngitis, ARF and RHD (C), the educational process has proven to be effective, with a median 20% increase in knowledge about RHD, evaluated through structured pre- and post-tests applied to more than 1,100 school children (O). • Some resistance from the Board of Education and Health was observed, mainly related to research procedures and the impact on the school routine (C). • At first, the main challenges were related to the lack of involvement of school representatives with the program and lack of understanding possible benefits. Overall, there was low parental engagement with the project with the poorest attendance to educational sessions seen in the lowest socioeconomic status areas. The proportion of signed informed consents was low (about 35%: 5,996 out of 17,000 children) especially among older students, even after the educational process. • There were also several challenges for follow-up visits. Phone contact with parents was often not possible because the children did not have the contact information, numbers changed frequently, and schools are not always authorized to disclose contact information. In addition, 35% of families failed to show up for scheduled appointments (C), this may presumably be, in part, due to patients being asymptomatic and families not being convinced of the importance of monitoring (M). • Some strategies, such as subsequent educational calls and flexible follow-up dates have been recently tested, with relative success (C). • The next steps of PROVAR are related to the diagonal integration of RHD screening in primary care (Other).

Table continued from previous page

Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
The benefits and harms of rheumatic heart disease screening from the perspective of the screened population[341]	Journal article	• Our observation of diminished physical activity among a substantial minority of asymptomatic children who were given an abnormal screening result represents an important issue for RHD screening (Other). • One worrisome observation in this respect is the fact that of the significant proportion of case respondents who reported feeling 'very worried' after receiving the result, less than half (42%) of their respective children were given a definite or probable diagnosis of RHD at the time of screening (Other). • Nearly all case respondents could recall the screening event (93%), compared to only half of the control respondents (50%). The fact that half of the control respondents did not recall the screening event is perhaps an indication of the minimal impact that the screening event had on those childre (Other). • 'Very happy' that their child had undergone the test (72% of case respondents, 80% of control respondents) (Other). • Fewer case respondents who recalled the screening event were found to have a 'good' understanding of what the screening test was for (8%) compared to control respondents (30%; $p < 0.001$). This is a curious observation, since we would perhaps expect those who received an abnormal result to have had increased understanding of the screening test following their diagnosis (and thus be more rather than less literate) (Other). • Another interesting observation was the fact that 41% of case respondents (and 23% of control respondents; $p < 0.001$) changed how often they sought sore throat advice following receipt of the screening result (O).

Table continued from previous page

Source	Type/document	Context (C), Mechanism (M), Outcome (O), Other
Latent rheumatic heart disease: outcomes 2 years after echocardiographic detection[342]	Journal article	• An oritentation video in local language (C). • Inconsistent medical advice by different health care providers decreases the motivation to adhere to regular secondary prevention (Other). • Challenging to explain the significance of subclinical disease and stress the importance of secondary prevention in asymptomatic children to parents and primary caregivers (C). • Descriptions of RHD control programmes over the last 60 years have revealed the importance of a single key contact for programme implementation. Sometimes this person is called the programme manager, the nurse manager or the register coordinator. Irrespective of title, having a single core person dedicated to developing and delivering the programme is a key component of care delivery, continuity and medication adherence (C). • Schools can provide a convenient way of accessing large numbers of young people in a single location. However, school attendance varies around the world; in some places children at greatest risk of RHD may be the least likely to attend school, or be accessible for screening (C). • Most screening occurs in schools and locating suitable rooms for screening and blackout materials may be challenging . Advance planning about the location and darkness of echo rooms is required (C).

E.5 Informal expert discussions

A total of 17 informal expert discussions informed the initial programme theory:

1. Remote health workforce expert (Australia)
2. Remote health workforce expert (Australia)
3. Remote health workforce expert (Australia)
4. Remote health workforce expert (Australia)
5. RHD screening expert (USA)
6. RHD screening expert (USA)
7. RHD screening expert (Australia)
8. RHD screening expert (Australia)
9. RHD screening expert (Australia)
10. RHD screening expert (New Zealand)
11. RHD screening expert (Uganda)
12. RHD screening expert (South Africa)
13. RHD screening expert (USA)
14. RHD screening expert (Australia)
15. RHD screening expert (Australia)
16. RHD screening expert (Australia)
17. Remote health workforce expert (Australia) (National Association of Aboriginal and Torres Strait Islander Health Workers and Practitioners)

E.6 Site engagement brochure

Orientation to SPLASH scanning for RHD in communities

Is our clinic ready?

This brochure provides information for clinics interested in Rheumatic Heart Disease screening using a SPLASH scan. It draws on lessons from the NEARER SCAN study in five clinics across the NT and WA. The study highlighted what helps scanning to become part of routine practice and key factors that can support this process. Not everything needs to be in place from the start, as readiness can develop over time. Strong clinic leadership is important, and the Menzies team will provide support along the way.

Who to train as a SPLASH scanner

We encourage clinic managers to discuss the scan training plan with all staff to find the best fit. Consider who is interested, available, and likely to stay in the community—local health workers are often the most long-term. Training a long-term GP or senior nurse can provide additional support to scanners and some trainees found having a 'scanning buddy' helpful. Seek input from community elders, schools, and local groups about heart scanning as well. Look for local RHD Champions.

SPLASH:
Single Parasternal Long Axis acquisition with a Sweep of the Heart (the simplified scan used for RHD screening)

ASUM:
Australasian Society for Ultrasound in Medicine (new online modules now created for SPLASH training)

Cultural sensitivity and awareness

- [ ] 1 Are there cultural considerations and sensitivities we should be aware of in relation to scanning in your community?
- [ ] 2 What is the clinic's approach to cultural safety in the workplace and in interactions with the community?

Clinic systems and scheduling

- [ ] 3 Could trainees have dedicated time to complete the ASUM online modules for SPLASH scanning? Is any additional support required (e.g. technical or language support)?
- [ ] 4 Could scanning time be scheduled periodically for training and afterwards? (e.g. screening events/clinics)
- [ ] 5 Could a process be created where individual scanners or the health service is notified once scans have been reviewed so that scan results (both normal and abnormal) are acted upon?
- [ ] 6 Could SPLASH screening be included in the clinic KPIs or routine performance measures?

Knowing who and when to scan

- [ ] 7 Could a recall list be used to identify people who are due for a SPLASH scan?
- [ ] 8 Could the clinic work with local schools to develop a consent process for adding SPLASH scans to school screening?
- [ ] 9 Could all staff be informed about the process for referring people for a SPLASH scan?

Team support

- [ ] 10 Could scanning be discussed at existing regular staff meetings (e.g. morning huddles)?
- [ ] 11 Could the clinic schedule regular check-ins with scanners to talk about how scanning is going?
- [ ] 12 Could the clinic facilitate regular chats or visits from the cardiac sonographer to support the scanners?
- [ ] 13 Could the clinic manager develop a scanning handover plan in case of management changes?

Technical set up and accessibility

- [ ] 14 Does the clinic have reliable Wi-Fi or mobile internet for uploading scans? What support or infrastructure is needed to ensure scanners have consistent access?
- [ ] 15 Is there an accessible secure place to store and charge the devices?

Do you need any additional support from the Menzies team to meet the readiness checklist requirements? If yes, please describe what support you need by emailing **nearerecho@menzies.edu.au**

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Maintaining scanner's skills

Timeline for training

	1	2
STAGE	**Connecting to community and clinic**	**Set-up period**
TIME	Unspecified	2–3 months
FOCUS	Relationship building	Planning & Toolkit
KEY ACTIVITIES	Schedule time for the Menzies team to meet and develop relationships and understanding of the community and its health service.	– Identify trainees – Discuss readiness Toolkit & checklist – Sonographer visit: introduce ASUM portal, scanning device, and training plan – Trainees start ASUM online modules

Clinic managers influence scanning

Screening events help with skills

3 **On-site training**

3–4 days

Hands-on learning

- In-person training with sonographer
- Review ASUM modules
- Practice scanning techniques
- Plan sonographer-supported screening events

4 **Local scanning**

2–6 months

Independent scanning practice

- Begin day-to-day SPLASH scanning
- Upload scans for review
- Receive feedback
- Participate in sonographer-supported screening events

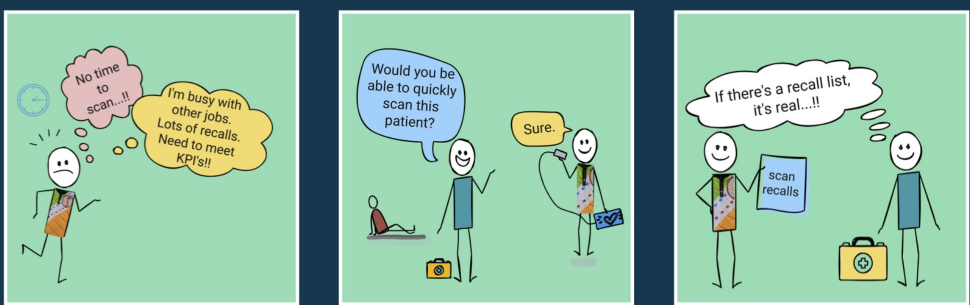
5 **Graduate SPLASH Scanner**

Upon 100 scans

Certification & focus

- Graduate as a SPLASH scanner
- Receive ASUM qualification
- Plan ongoing scanning prioritising ages 5–20 yrs, pregnant women, ARF cases and priority 3 RHD follow-ups

Connecting scanning to workflows



Success Stories

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The following stories are real examples from the work we have done, showing how staff in different roles took practical steps to make scanning part of everyday work.

At one clinic, an Aboriginal Health Practitioner created recalls in their clinic's medical records for yearly SPLASH scans for children aged 5–20 and currently pregnant women in their community. They helped run a scanning station during a Youth Sports programme, where they said they were able to do "two or three [scans in a row]." They also felt supported by visiting cardiac sonographers, noting that "they keep us straight." Importantly, local cultural systems were considered in helping who to choose to train, with male and female staff sharing responsibility: "That's why it's good to have me and [another scanner here], he does the male, I do the female....[it's] all about respect."

Aboriginal and/or Torres Strait Islander health practitioner / health worker / community worker

Clinic manager

At one clinic, the manager actively supported the programme and motivated staff. They encouraged trained staff to scan, saying "we need to push [scanning]...we need to start doing this," and highlighted its benefit to the community: "it's so awesome to see these guys do something that can have such an impact on the people of [this community]." The manager also looked for opportunities to link scanning with community events, asking the organiser of a local school holiday program "is there any way we can combine [scanning] with the program?" Additionally, they coordinated visits from cardiac sonographers to provide hands-on support.

Nurse

At a third site, a nurse helped organise a fortnightly SPLASH scan clinic for women in early pregnancy. They also organised scanning to be part of a larger community health promotion event. They noted that referrals for scans increased after this, likely because people saw scanning happening. The clinic staff began to see scanning as part of their everyday work. Overall, the nurse described the programme as "fully supported... we just led the way."

General practitioner

At another site, a GP became a strong champion for point-of-care SPLASH scanning. They often worked alongside an Aboriginal Health Practitioner to scan, saying it was good to give "little bits of feedback to each other." This GP helped make scanning everyday work in several ways. First, by setting up a referral process with the midwives ("I emailed [the midwifery manager] to ask, can we make it part of the normal process? And then the midwives "kicked it off"). Second, by encouraging colleagues to refer children for scans ("Over time they were like, 'oh, the GP might want to scan this child'"). And third, by sharing stories in morning meetings about how scanning improved care for patients, such as speeding up retrievals when severe valve disease was detected.

Deciding when to offer scans

MRFF2041013

E.7 Summary of findings for stakeholder feedback

This one-page summary was circulated to representatives from each cadre and implementation site to support stakeholder feedback on the refined programme theory.

1. Scanning can become part of routine work, but only under the right conditions.
2. Scanners are motivated and capable, but success depends on the right support.
3. Making scanning legitimate is vital so scanners feel confident justifying it to colleagues and patients.
4. Legitimacy can be reinforced in three main ways:
   a. Verbally: through team-wide messages from managers, check-ins with scanners, and clinical referrals.
   b. Socially: via expert visits, training people in pairs or groups, and allocating protected time for scanning.
   c. In writing: by creating recall lists, integrating scanning into KPIs, and training staff with authority (e.g. GPs) to advocate for these changes in facility systems.
5. At the same time, scanning generates hidden work, both practical (charging devices, uploading scans, troubleshooting) and social (deciding when to scan, explaining to patients, navigating cultural expectations).
6. When this invisible work is shared across the team, scanning feels manageable and sustainable; when it falls to one person, it becomes fragile and harder to maintain.
7. Because this hidden work is often tiring and emotionally demanding, it needs to be recognised and supported for scanning to become part of everyday care.

E.8 Final CMOCs and supporting evidence

This table presents the final set of CMOCs developed through analysis across the three empirical phases. Each CMOC is supported by evidence drawn from multiple data sources and, or to relevant substantive theories.

Final CMOCs and supporting evidence

Final ID	**Draft IDs**	**CMOC**	**Phase 1**	**Phase 2**	**Phase 3**	**Substantive theories**
1	P2.24	When multiple staff are trained as scanners and visibly scanning (C), it may be considered normal work within the clinic (O), because seeing multiple colleagues scan makes it a shared expectation (M).	NA	“Multiple people to solidify that this is what the health practice does, [create] more conversations about it” [FGGP4]. [When asked directly if people see scanning as a clinic activity or an individual project] “Yeah, basically [the other clinic staff] just leave it up to us with the scanning, to figure it out and all that” [FNCHW1].	Site 3, which was the only site with multiple active scanners (>=3 staff completing >=5 scans across >=3 months), also had the highest mean response for the NoMAD item measuring shared understanding among clinic staff (4.44), compared with 3.0–4.2 at other sites. This supports the idea that visible participation by multiple staff reinforces a shared understanding of scanning across the clinic.	Normalisation process theory[138], complex contagions theory[140]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
2	P2.41	When staff with authority (e.g. GP or senior nurse), time capacity, and a genuine interest in scanning, are trained as scanners (C), they become personally invested in the programme (M), and advocate for changes to clinic processes that support scanning (O).	NA	“I emailed [the midwifery manager] to say ’I’m doing scanning can we make it part of the normal process?’ And they said ’yeah, sounds like a good idea’, and then with the midwives it kind of kicked off from that. So it was contacting managers.” [GP5]. “Nurse 3 was trying to do the [scanning] roster [for antenates]... tried to call a meeting” [N3(2)]. “At site 3, forwarded text from Nurse 3 to team member: Nurse 3(3) was [rostered yesterday]... I will chat to them tomorrow. I’ve been sitting in for two weeks and there ain’t no way I could have done it” [OFN3]	NA	NA
3	IPT5, P1.6, P2.23	When FNCHW scanners have a nurse or GP scanner buddy to scan with (or call on if needed) (C), they are more likely to scan (O), because they feel supported (M).	“[FNCHW3] loves ‘sticky stamping’ with [Nurse3], so when [Nurse3] is here, [FNCHW3] has far more confidence so it’s an example of having confidence when you’ve got the right buddy with you” [CM3] “I’ve got [GP5] to relate to... we’ve got two sets of eyes... we can both learn off one another... it’s useful when you get stuck” [FNCHW5] “When the doctor is not here and it’s just me and [FNCHW2(2)], we kind of get lost in doing it really properly with the science so we do it when the doctor is here to guide us” [FNCHW2].	know [FNCHW3] and I can go out in pairs, partner and go out [to scan]” [N3]. “It’s nice just giving little bits of feedback to each other” [GP5]. “But it’s just me, so I don’t... you don’t really have anyone to bounce off” [FGN5]. “[FNCHW5] is really good on the scanner but they often get me, we do our scans together” [FGGP5].	From qualitative data there were four FNCHWs with GP/nurse buddy pairs. They completed a median of 20.5 scans (IQR: 18.8–23.5), compared to a median of 9 scans (IQR: 3.0–12.5) among those FNCHWs without.	NA

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
4	P1.13, P2.29	When cardiac sonographers visit a site for ongoing support (C), scanners are more likely to scan (O), because expert presence makes them feel confident (M1) and that scanning is acceptable to prioritise (M2).	"Good thing is I'm hoping that come [the cardiac sonographer's] visit, the hands on, and them being around [will help]" [CM2].	"Definitely helped with [cardiac sonographer] coming out to [Site 4] twice now, just for two days or so and lifts up confidence and gets the momentum going again" [FGGP4]. "It was really good when [cardiac sonographer] came back... cause in this you need to lean on something, like that, they keep us straight" [FNCHW2]. Talking about scanning [with] cardiac sonographer today: FNCHW immediately said it is much easier, why? 'Because she can help me and I can ask her things.' [OFN3] "[Other scanner at Site 5] is confident when [cardiac sonographer] visits and then their confidence drops" [GP5].	Scanners were significantly more likely to perform at least one scan on days when an expert scanner was present compared to days without an expert (OR = 18.15, 95% CI: 10.87–30.26, $p < 0.001$). The average number of scans on expert visit days was also approximately 50 times higher than on non-visit days (3.58 vs. 0.07 scans per day).	COM-B theory[235], self-efficacy theory[230]
5	P1.45	When scanners have had few opportunities to practice (C), they are less likely to scan without a visiting sonographer present (O), because skill decline over time reduces their confidence (M).	"I still got more to go... we have to do it more than once a week to really get it inside our head" [FNCHW3]. "I did a few scans on my own, but I think I'm lost at doing it a bit" [FNCHW2].	"I was going to say practitioner confidence, I think that's a big thing. FNCHW4 is very capable at scanning but hasn't done very many recently, and therefore she's probably lost her confidence. Would definitely ask me instead, if I suggest to her, she'll go 'oh no no no you do it' because she's kind of forgotten and she's lost confidence and it's that getting that momentum and that confidence and building that up. It's not so much the patient's confidence that is the issue it's the practitioners" [FGGP4]. "[From a cardiac sonographer about a scanner] they were very rusty and needed lots of instruction" [OFN3].	As above	Ebbinghaus learning curve[229]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
6	P1.40, P2.81, P2.82	When supervision for FNCHW scanners is delivered off-site and remote supervision via any mode of communication is not a usual practice (C), engagement is limited (O), because FNCHWs see it as optional and deprioritise it in favour of more immediate tasks (M).	"We just haven't managed to get any good conversation [about scanning] on WhatsApp yet" [OFN3]. "In the WhatsApp group, like we all get the same message, but then I'll be the only person that responds" [N4]. "In today's meeting we were talking about how the WhatsApp group hasn't really been engaged with by people here" [OFN3].	"[Cardiac sonographer] We need to keep encouraging communication from the site end... we have really tried to make the 'check-ins' work over the last year – emails, SMS, calls, and Zoom" [OFN3]. "[Cardiac sonographer B] I am more than happy to provide feedback on image quality, check if scans are on Tricefy and troubleshoot downloading if someone reaches out to me. But as [cardiac sonographer A] said, checking in with the non-experts... has not made any apparent difference in the past" [OFN3]. "[Other implementation team member] I am surprised if checking in with [scanners] makes no difference, this is different to my experience." [OFN3]. "And do you think that [the reason the FNCHWs aren't using WhatsApp for support as much is] because it maybe feels a little bit less familiar? You're not as used to using WhatsApp as the doctors might be?" (Interviewer) "Yeah, I'm not a WhatsApp fan. I don't know about the others, I don't know why they're not engaging" [FNCHW2]. "[From expert scanner who has had success with remote support]: Chat with [scanner] tonight, on WhatsApp, she has an idea for how to get scanning happening in [her site]" [OFN3].	NA	Street-level bureaucracy[139]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
7	P1.41, P2.84	When scanners seek remote support and receive prompt advice (C), it reinforces the clinical value of the programme (M), which increases their willingness to scan (O).	NA	"Having the ability to have [support] on the WhatsApp group and being able to get that feedback when you're doing it, knowing that it's there and the response times are very rapid so we get feedback really quickly. That's all very, very helpful" [N3]. "Makes us feel that there's someone out there that we can just bounce it off" [N3(2)]. "I find the text feedback like the WhatsApp group just such a support. To be able to get the cardiologist's opinion on something like you know that day like just gives you so much more confidence in how useful [scanning is] so you want to do it more." (GP5) "I can text through to the name and [the cardiologist] is awesome, you can get an answer within minutes of what they think of the scan. I think just having that support and being well organised I guess makes it feel like you are not just doing these scans for no reason" [FGGP5]. "There's been good communication through the WhatsApp" [FGGP4].	NA	NA

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
8	P1.24, P2.55	When FNCHW and nurse scanners have dedicated time set aside for scanning (e.g. screening events) (C), more scans are done (O), because this protected time within their workflow allows them to prioritise it (M).	"It is about carving out dedicated time [for scanning]" [CM3]. "Even if we could spend an hour doing RHD scanning during the week. We finish off but if we could spend an hour at five that'll give us time to do some scanning, if they could come up with that routine" [FNCHW3]. "Set times so you can scan and you can just sit in here and scan everyone that comes in" [FNCHW3(2)]. "I think definitely having screening days is a good idea" [CM5]	"Even if we had a day a week, or even an afternoon a week, but I just know that if we didn't have any additional capacity, I would be in the back of my mind thinking, shit, I've got to pick up this kid, oh my gosh, I've got to do this. Oh god, I cannot forget this" [N3]. "Allocate a time, a day, that is strictly a blockout day" [FGGP4]. "The scheduled events are much easier for us. It also frees up a bit of time for us because there's often some allocation of clinic staff" [N3(2)]. "It's purely a capacity issue for opportunistic, it's not lack of will, it's purely capacity" [N3(2)].	At Site 3, the only site to hold regular events with scanning, on event days scanning averaged 8.3 scans per scanner per day compared to 0.1 scans per day on non-event days.	NA
9	P1.33, P2.53	When FNCHWs can scan children who are already gathered (e.g. at schools or youth programmes) (C), more scans are done (O), because with the logistical responsibility removed, scanning feels like a manageable task (M).	"All the kids they're all going to be in one spot. That's fine like having that event or something for us to work with to go and do it is a lot easier. We just don't have the resources to organise something ourselves" [CM2]. "I'm just hoping maybe after the break, we can if we can just go to school and do it there with them" [FNCHW2]	"Yeah, we see at the last [public health scanning event], when we were at the Youth Center, they put it on Facebook, and then some of the girls that walked in 'oh, we seen it on Facebook. Yeah, that's cool.' " [N3]. "We had a station for heart scans and we went up during [a local youth] programme, like with the kids sports, and we were just getting like two or three [scans] at a time" [FNCHW2] "I think doing those kind of focused scanning days would be good. Like if I could even go up to the school next semester, yeah, we can see if we can organise like a day at the school where everyone gets scanned." [N5].	As above	Invisible work theory[254]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
10	P1.30, P2.51	When a clinic has a consistent manager and time to build a working relationship with the external programme team (C), the relationship fosters a sense of shared commitment (M1) and accountability (M2), which drives the manager to make practical changes to support scanning (O).	"Having the Menzies partnership as a long-term thing, [chief investigator A] and [chief investigator B] being the paediatricians here, and [one of the other investigators] as a long-termer as well. So there's this constant and continuous flow, flow of people who have a real strong interest in this space [which helps]." "I said to FNCHW, we need to push [NEARER SCAN], you have to do it, so that first week they go in to have a go with it... but we need to start doing this" [CM2] "I got in touch with [external youth organisation] last week and was like 'buddy, we need to get some kids for [FNCHW2] and [FNCHW2(1)] to get some numbers, is there any way we can combine it with the school holiday?" [CM2].	"Knowing that you guys are coming out [to visit the site] is also like crap, let's get sorted. Like they are coming out we need to get this done" [CM2]. "It's fully supported. Oh yeah, we just lead the way." (FGNurse3)	Sites with consistent clinic leadership (Sites 2 and 3) reported the highest scanner-perceived managerial support in the NoMAD survey (4.3 and 4.2). In contrast, support was lower at sites with leadership changes, such as Site 4 (2.3) and Site 5 (3.0). Site 1 showed an initial high level of support, which declined with manager turnover (3.5 by late implementation).	Normalisation process theory[138]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
11	P2.115	When clinics experience high manager turnover and new managers face competing demands without clear guidance or working relationships with the external programme team (C), the resulting ambiguity (M) means manager support for scanning tends to remain nominal (O).	"I missed out who got trained, as well" [CM4]. "I think he had a bit of an issue with uploading the echos, I'm not sure how that's going" [CM5].	"I couldn't even tell you honestly if they are doing any echos, you know, echos or anything at the moment as part of the NEARER SCAN programme, I don't, I'm not even sure that they are" [CM1] "To be honest, I didn't get any handover [about the programme]... maybe the new programmes run by external stakeholders are not identified as a priority, I think that could be a reason why it's not mentioned" [CM4]. "Yes they [the clinic manager] keep changing they don't say why" [FNCHW4(2)]. "[Having new managers has been disruptive] because they don't even know what the NEARER SCAN is" [FNCHW1]. "Manager has been on sick leave and then we had an interim manager and then another interim manager. So I think it's one of the big issues" [GP5]. "I know that [previous manager] is [supportive]. You know, really on for this but [I'm] not quite sure about the other managers, yeah, whether or not they allow us that time. I know [the previous manager] would but she's not in that role anymore" [FNCHW1(2)]. "It's just, you know, crisis management day-to-day rather than having a bigger picture understanding of how things can work well" [GP4, reflecting on acting as CM4].	NA	NA

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
12	P1.8, P2.38	When clinic managers mention the programme in staff team communications (e.g. morning team meetings, celebrating scanning efforts) (C), FNCHW scanners are more likely to prioritise scanning (O), because it signals that scanning is a legitimate clinic activity (M).	"We spend a lot of time advocating for these things in morning meetings and just day to day" [CM3]. "Afternoon tea with the others in the clinic, clinic manager, AHPs, nurses to celebrate FNCHW2 [after finishing training]. All very proud and supportive, FNCHW2 saying 'If you guys see someone for an appointment let me know to do a scan"' [OFN2]. "[At site 4] asked for show of hands who was aware of NEARER SCAN. Out of 13 staff, 5 aware – all [local Aboriginal people]. Contrast with [Site 3] meeting where manager knows all scanners" [OFN4].	"FNCHW3 introduced themselves [as a scanner] at all staff morning meeting after graduating and receiving a scanner shirt" [OFN3]. "[When asked what we could do to help with scanning implementation at site 4] 'Normalising the idea of scanning within the practice so that the GPs, and the nurses, and the CHWs, all know that we are doing this and this is why we are doing it and it becomes a normal part of what we do"' [FGGP4].	In the NoMAD results, managerial support had a significant, weak positive correlation with shared understanding: (ρ = 0.37, p = 0.032).	Role legitimacy[252]; social norms theory[343]; normalisation process theory[138]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
13	P1.17, P2.45	When clinic managers emphasise the benefits of scanning for the community (C), it resonates with FNCHWs' commitment to caring for the community (M), which makes them more willing to participate in scanning (O).	"[Text message from CM2]: I'm so so proud of you [FNCHW]. I hope you're proud of yourself... It's so awesome to see these guys do something that can have such an impact on the people of [Site 2] and their lives. Keep up the good work" [OFN2]. "Thank you all for this opportunity and new skill we can now have in our local clinic for our community" [Message from FNCHW2] [OFN2].	"My name is [FNCHW3], I'm a community health worker, and also I'm a NEARER SCANNER, and I'm so excited to do some scans today, wearing this new deadly shirt I've got" [OFN3]. "And it's something that they can achieve on their own. Something super important. For them, 'I did this"' [CM2] "I feel proud to be [scanning], looking at that kid... looking at his face makes you feel emotional" [FGFNCHW2]	NA	NA
14	IPT2, P1.31, P2.52	When clinic managers regularly check in with scanners about their scanning (C), it signals that scanning is important amid competing demands (M), which reinforces that scanning is legitimate to prioritise (O).	NA	"Guys do you reckon, you can smash out 15 [scans]?" [CM2]. "It's the next step, which is how does the manager actually build that into their programme and is that being done? Is there regular check-ins saying how you're going [to the scanners]? Have you got a couple of scans this week? Or whatever like that, just regular check-ins, I think that's the next step. It's not being done here" [FGGP5]. "Now there is an expectation from the clinic that all women will get a scan. Once it becomes an expectation of the clinic it happens" [FGGPO].	NA	Role legitimacy[252]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
15	P1.34, P2.69, P2.70, P2.71	When the practical tasks needed to keep scanning operational (e.g. charging, locating the device) are both accessible to and expected of all scanners (C), it signals that scanning is a shared responsibility (M), making scanning activity more likely to be evenly distributed across trained staff (O).	"So [FNCHW5] normally has his in his room." (Nurse5) "The scanner usually stays in here, Nurse5 is in the [building] out there. So if she wants to scan, she has to come grab the scanner" [GP5]. "[FNCHW2] suggests Lumify can be kept in [the clinic manager's] office, to access when using" [OFN2]. "[FNCHW2 and FNCHW(2)] share the one scanner. There are no issues with either of them accessing the scanner. They keep it in the manager's office because their consult rooms are used for on call which means there can be numbers of other people in the room. Manager's office is easily accessible" [SR].	"We've had issues with the Lumify not being charged in the beginning, but they now live in our locked office and have their own little set of cable cords, and it seems to be working" [FGGPO]. "Now [the device] lives in our locked office... we have them all in the same office" [FGGPO(2)]. "[IT support person] is amazing and has [the devices] plugged in in his office [which is accessible]" [OFN3]. "We will always find one, one of us always finds one" [FGN3]. "[Site 5 scanner] stated that after the initial training they felt confident with scanning but has lost that through not being able to obtain the Lumify [from other scanners]" [OFN5]. "It's in my room" [FGGP4]. "The one I am using at the moment was in Nurse5's room but she was not scanning so now it's in my room" [FGGP5].	Site 5, which had the most reports of certain scanners feeling they lacked access to scanners, recorded the highest Gini coefficient (0.48), indicating scanning was concentrated to one scanner. In contrast, Site 3, which had a strong culture of sharing devices, had the lowest Gini coefficient (0.10), suggesting scanning was more evenly distributed.	Invisible work theory[254]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
16	P1.35	When devices aren't ready for immediate use because the operational tasks (e.g. charging) have not been done (C), scanners may abandon their intention to scan (O), because of the frustration that arises when the expectation of scanning as a ready-to-go task is undermined (M).	Device required charging during which time FNCHW4 continued her clinical work. I notified FNCHW4 when there was sufficient charge on the Lumify however she appeared to have lost interest in heading out to community [SR4].	"These machines were being a bit dodgy with the charging... there's a few times we had some issues with them, they'd been on charge for days or hours and then they weren't fully charged" [N3]. "Knowing that the equipment's working and charged and it's already to go, that speeds things up" [GP4]. "[Interviewer] When devices are conveniently stored and charged, scanning feels more seamless and gets done more often. [Sounds of agreement]" [FG of scanners]. "I don't use it yeah, because not on charge" [FGN3].	NA	Invisible work theory[254]
17	P1.1, P2.9	When other clinic staff, especially GPs, refer patients to FNCHW or nurse scanners for a scan (C), it acts as a social nudge that legitimises (M) the prioritisation of scanning (O).	"[The GP] is pretty on to it, he pulls us up, asks us, or even brings patients to us" [FNCHW5]. "I remember the last time [the paediatrician] was here, he called me and he asked me if I had some spare time to go with him to do a heart scan on a patient. He's really good at doing that, very supportive. He likes to help us out to learn more about scanning" [FNCHW3].	"We're now getting GPs coming and saying, 'Hey, I've just got a kid can you just do a quick scan?"' [N3]. "Sometimes doctors will come 'can you do the scan?' Or, a nurse comes, 'can you do the scan?"' [FNCHW2]. "[Scanning is] not done, we don't get to do any scanning, [but] when [the paediatrician] was here, the senior people, send the text message 'do you or anyone wants to do scanning come down"' [N3(2)].	NA	Nudge theory[344]; role legitimacy[252]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
18	P2.13, P2.18	When scanning is visible to other clinic staff (e.g. scanning events) and is explicitly supported by line managers (C), other clinic staff are more likely to refer patients for scans (O), because scanning is collectively seen as an expected clinic activity (M).	NA	"Nurse at site 3 said it [the reason they are now getting scan referrals when they hadn't previously] probably is because of the promotion during [screening event] and new clinic staff seeing it more as standard practice" [OFN3]. "[Referrals] just came with time, [once the other staff] were aware that I like to scan all the kids, because they would call me in for whatever reason and I would then offer a scan, then they would be like 'oh okay this is something that the GP is keen on doing.' So I think over time they are like 'oh, the GP might want to scan this kid, he hasn't had a scan already"' [GP5]. "I emailed the midwifery manager to say 'I'm doing scanning can we make it part of the normal process?' And they said 'yeah, sounds like a good idea', and then the midwives kind of kicked off from that. So it was contacting managers" [GP5]. "Getting that support from higher up manager. I think yeah, it was definitely part of it. I think they were very keen to get on board anyway, but yeah, it was definitely part of it, the manager" [GP5]. "It's to do with the doctors that know we do exist, but we don't get much referrals from other staff" [N3].	This context can be clinic-wide, as seen at Site 3 with the highest NoMAD scores across the sites in both shared understanding (4.44) and managerial support (4.44), or within specific teams in a clinic as demonstrated by the qualitative accounts of a GP and the midwifery team at Site 5. The *and* of the context is reflected in how at Site 2 with the second highest scores of both shared understanding (4.20) and managerial support (4.25) but did not have regular visible scanning occurring like in Site 3 which had regular event scanning.	Normalisation process theory[138]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
19	P2.64	When FNCHWs' workflows are dominated by delegated or KPI-linked tasks and there are no clear social or formal expectations to scan (C), it is hard to prioritise (O), because it feels optional (M).	"Mostly I'm going work for the nurse" [FNCHW3]. FNCHW at Site 3 performed 2 scans and was then needed in liaison role. [OFN3]. "Busy doing other stuff as well with short staff and with driving" [FNCHW2]. "I haven't scanned anyone yet. Always busy, flat out, working, need to catch up on what we do" [FNCHW(2)]. "Just finding that extra 10 minutes to do echoes is probably a bit daunting when you've got lots of competing priorities" [CM5].	"Well, we've got our own jobs... we're not recognised [for] that RHD scan that you said, okay, so it's in our time" [FNCHW1]. "We're just getting told what to do here, there, and everywhere, you're not really valued" [FNCHW1(2)]. "Compared to [regional hospital NEARER SCAN site] where 'The organisation is expecting us to do it, there is a KPI on screening in everyone"' [FGGPO]. "How do you decide what work you do in the day? Even the cleaners may ask for help, and we help them to move furniture or something" [OFN2 in discussion with FNCHW]. "If [scanners] can't see that scanning is important or a legitimate bit of a part of your role, then the problem with that is that you've got all these other jobs that are going to be prioritised" [FGN5]. "But I guess the scans aren't... part of KPI's and... it's not part of the managers priorities and what they're overseeing [Nurse5] do, I guess. I think that the biggest barrier as to why they don't get as many numbers" [GP5].	A decline in scanners' scoring of the NoMAD item "It's easy for me to fit NEARER SCAN into my work day" from Phase 1 (4.29) to Phase 2 (2.56) suggests that scanning became less embedded in daily workflows over time. This may indicate that, without the initial expectations present immediately after training, scanning was harder to prioritise alongside other tasks.	Role legitimacy[252]; street-level bureaucracy[139]; normalisation process theory[138]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
20	P2.66	When scanners have authority within the clinic hierarchy (e.g. GPs) they are trusted to manage their own workflow (C), so they are more likely to be able to prioritise opportunistic scanning (O), because this autonomy gives them the confidence to decide when scanning is appropriate (M).	NA	"[Interviewer: Do you feel like those competing responsibilities has a different impact for doctors vs FNCHWs? Is it easier for your to justify a scan?] "Yes probably, I am not expected to pick up patients from the waiting room, maybe they do feel more of a pressure if waiting room is full to get patients through, whereas in my role I can take my time" [FGGPO]. "[For FNCHWs, the manager looks at how many patients they are seeing. . . [whereas] it's me who decides how often I see which patients, so my workflow is in my hands" [FGGPO]. "A doctor can make it bit more independent decisions about what they do or what they need to focus on. . . [whereas] [Nurse5] has people kinda like watching those numbers [of key performance indicators]" [GP5].	NA	Professional authority[258]; street-level bureaucracy[139]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
21	P2.34, P2.35	When there is a recall system for scanning that is visible to all staff (C), opportunistic scanning becomes easier to prioritise (O), because the recall provides visual prompts for action (M1) and makes scanning feel legitimate (M2).	NA	"We actually have a list of all our pregnant patients and we've incorporated the screening onto that. It's a column on an Excel spreadsheet. When someone comes in, we look and go 'oh, she hasn't had an echo, we'll do it!"' [FGGPO]. "We have a NEARER SCAN recall, 'Has had a scan', 'Is it reported?' it highlights red. That has worked with our antenatal patients because the midwives have put that recall on and ticked those boxes. So that's our spreadsheet" [FGGP5]. "Recall, something that pops up on the screen, makes it feel legitimate" [FGGPO]. "But to have that full [recall] list and then print it, these guys [FNCHWs at Site 2] are visual. And once you've knocked it out [saying] 'you're down 6 pages now, guys, look at us go, do you reckon you can knock off another page?"' [CM2]. "Recalls are a good idea, because people work off recalls" [FGGPO].	NA	Nudge theory[344]; role legitimacy[252]
22	P1.26, P2.58, P2.59	When children present unwell for reasons other than suspected ARF/RHD (C), FNCHW and nurse scanners often choose not to offer scanning (O), because offering an optional check feels inappropriate when there are acute care needs (M).	"Most of the time they are sick already so people kind of just want to come in and get their treatment and go which is understandable. And so then it's quite hard to kind of like say 'oh well actually stay and do this as well', especially if it does take us a bit longer because I feel like I'm still not very comfortable at it" [N4].	"I've been told we need to do opportunistic scanning for patients... it doesn't make sense to me because they're unwell... they've got something else that's more important to them at that time and then going and asking them if I can scan the child or the other children that are there, it's massive you know. It feels... [inappropriate someone else says] yeah it feels that" [FGN1]. "Yeah, no, if it's not going down that pathway [ARF workup], yeah, I wouldn't think about doing it" [FGN3]. "I asked her [other FNCHW at clinic 2] about opportunistic scanning. She didn't think she would do that unless a child presented with symptoms" [OFN2].	NA	Street-level bureaucracy[139]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
23	P2.57	When scanning is offered during a quick visit for a specific reason (e.g. bicillin) (C), participants seem less likely to agree (O), because they want to limit time in the clinic (M).	“They just want to come in do that [one thing], you know, their bicillin or whatever, they come in for that” [N3]. “Some of them [say when declining scans] ‘oh, we already, seen the doctor”’ [N3].	“And sometimes [patients] come and they want to get their LAB and we are hopeful to offer a scan and they say I’ll come back tomorrow, maybe later, maybe another day. So that’s something it’s not helpful” [FNCHW3]. “It’s got to do with the patient willing to to have it done because... we do ask some [say] ‘tomorrow’ and we know that’s a no” [N3].	NA	Street-level bureaucracy[139]
24	P2.60	When children become restless during a long appointment (C), scanners are less likely to offer a scan (O), because they want to finish core clinical tasks while the child is still engaged (M).	“They might engage a bit easier if it’s just that they come in it takes 10 minutes, they just do the scan and that’s done rather than in an appointment, which might already take an hour... I think what we’re doing at the moment, well not I think, it’s not really working, we are not getting them done” [N4]. “Health checks are sometimes a luxury” [CM3]. “I find that school age check is already really long, both to the clinic, but also for the child and the family... the kids get bored and want to leave and the parents kind of get bored and want to leave, already like the volume of like how long but then adding [scanning is] one of the things that makes it quite hard” [N4].	“When you’ve got really high flow rate of patients in the clinic in child health... you’ve got this incredibly narrow window to capture as much as possible before the child starts getting upset. The mother then says, ’that’s it - done’ and they go home... and then, of course, you’re just looking down your priority list, and it’s [scanning] just not there, right?” [N3(2)].	NA	Street-level bureaucracy[139]; invisible work theory[254]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
25	P2.94	When FNCHWs work in their own community and encounter eligible scanning participants where a cultural protocol prohibits interaction (C), they choose not to scan them (O), because they feel responsible for upholding cultural norms to maintain respect (M).	As above	“It does [stop us from scanning sometimes], it does yeah, cultural barrier” [FGFNCHW3]. “That why it’s good to have me and FNCHW2(2), he does the male, I do the female. The cultural barrier is all about respect” [FGFNCHW2]. “Actually one barrier, I think we haven’t actually said amongst us is we’re all female scanners” [FGFNCHW1]. “Sometimes I feel uncomfortable scanning males...[and] poison cousins stops us from scanning yep, if it’s a boy or boy and girl, yeah, we can’t talk to each other or go near each other or touch each other because they’re poisoned cousins” [FNCHW3].	NA	NA
26	P2.68	When FNCHW scanners work in their own community and carry substantial emotional and family/community responsibilities (C), cumulative fatigue reduces their mental and physical bandwidth (M), which may lead them to deprioritise non-urgent tasks like scanning (O).	As above	“But sometimes... you go to work, [and it] make you feel extra tired, because sometimes work don’t stop, you’ve got to still worry about heart problem and stuff like that [outside of work]. Humbug [a local term that means unreasonable or excessive demands from family or community] after work” [FNCHW3]. “I had to stop people from humbugging [FNCHW]... [the patients say to her] ‘hey, I just want this. I just want my tablets. I just want this. I just wanna go.’ It’s non-stop... the constant humbug in here, and you’re seeing 10 different people, and once that noise is gone, you don’t feel as much pressure” [CM2]. “It’s tricky for [FNCHW4]. She’s been called in lots of different directions... and then has a lot of family, humbug, family responsibilities on top of that. So I think for her to even have some breathing space, never mind think about doing scanning. It’s just not feasible” [GP4].	NA	Invisible work theory[254]

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27	P2.1, P2.2	When GP scanners offer opportunistic scans in a busy clinic environment (C), the consent process may be quicker and involve less patient education (O), because GPs consider brief information sufficient for consent at the screening stage (M1), and patients may be more willing to consent (M2).	NA	"My consent and education is fairly brief. I will often just like come into the room and just ask do you mind if we just do a heart checkup?" [GP5]. "I feel when I am doing the scan I don't have time to explain what I am doing, what it is" [GP4]. "It is just a quick thing... I don't think it needs a lot of consent and explanation... if most of the times [the result] is going to be normal" [GP5]. "[In response to a GP from another site asking if they take the time to explain RHD at regional hospital NEARER SCAN site] A little bit, depends on the woman and how many people in the waiting room. Depends on how accepting, or health literate I guess, or high risk... so pretty variable" [FGGPO]. "I feel the same, it's about how it's sold and how it is talked about" [FGGPO(2)]. "If AHPs are doing a lot of education that's not a bad thing because you know it's a good public health message and they can talk about it and their family groups. [But] if you're looking at building [scanning] as easy everyday thing, I think you can keep the consent and the education basic until actually there is [an abnormal finding]" [FGGP5]. "We were given resources and a video for the consent process, right? We found that there's no time for that and pregnant women don't seem to sort of want to seek out that basically, they accept the scan for their heart" [FGGPO].	83% of GP scans occurred when no study team member was on-site (as a proxy for opportunistic scanning) vs 13.8% for FNCHWs. GPs were significantly more likely to scan during these times than FNCHWs (OR 29.7, 95% CI: 13.8–68.4, $p < 0.001$, Fisher's exact test).	Self-efficacy[230]; street-level bureaucracy[139]; professional authority[258]

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28	P2.4, P2.5	When FNCHW scanners offer opportunistic scans in a busy clinic environment (C), the consent process may take longer and involve more patient education (O), because FNCHWs see it as their role to explain RHD and scanning in a relatable way (M1), and patients may feel more comfortable asking questions in the absence of language and cultural barriers (M2).	NA	"When they see us doing [scans] they get the idea of what's happening with our heart... some of them in the community doesn't know what's happening to them. They don't know how long they are having [penicillin injections] for. It's up to us to give them the feedback" [FGFNCHW1]. "We are not going making decisions and telling them that we're going to [scan]" [FNCHW3]. "It's good for them to see their own people doing stuff like this, they feel comfortable... you can giggle, you can laugh, you can talk about the scan, you show them their heart" [FGFNCHW2]. "[Doctors] don't really explain it properly. So most of the time, they'll ask for us to go sit in with them, so then we can explain it thoroughly instead of using scientific words" [FGFNCHW1(2)].	NA	NA
29	P2.7	When FNCHW or nurse scanners have the opportunity to scan in schools but feel unsure about the consent process (C), they may choose not to scan (O), because they are concerned about doing the wrong thing (M).	NA	"But then what about their consent form [at the school]? Is that going to be a barrier? Last time there was a bit of a barrier" [FGFNCHW1]. "Nurse at site 5 needs consent forms to scan kids at school" [OFN5]. "Consent is a big thing because you don't want to go wrong. It has to be an easier process... We try scan at the school but consent is an issue" [FGFNCHW1(2)].	NA	NA
30	P1.37, P2.73	When image upload issues (e.g. internet connectivity or upload app errors) are frequent and unresolved (C), scanners may stop scanning (O), because they anticipate the effort won't deliver clinical value (M).	NA	"[Connectivity and upload issues have] been a big disincentive because it's been well I can do the scan, but I'm gonna have to take time to try and troubleshoot to get uploaded" [GP4]. "When we first started we had a lot of issues uploading, and that was definitely a barrier and that's now gone away, which I find helps me a lot, I'm not having to spend half an hour going into settings and testing it out" [FGGPO].	NA	Invisible work theory[254]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
31	P1.38, P2.74	When image upload issues (e.g. internet connectivity or upload app errors) are frequent and unresolved (C), scanners may delay uploading (O), because repeated failures make delayed uploading an accepted norm, even if scanners know it's not best practice (M).	"I have done scans but I haven't uploaded any" [GP5].	"Sometimes scans have sat there for a long time and just not got uploaded because I haven't had time to talk to anybody... in the past it's been 'I can't be bothered to' it takes the time to do the scan, takes the time to upload. It's just gonna not be worth it? Can't face that" [GP4]. "Local scanners cannot be expected to spend the amount of time currently required to ensure images are being sent" [SR3].	NA	Street-level bureaucracy theory[139]
32	P2.76, P2.72	When upload issues persist despite local attempts to troubleshoot (e.g. home WiFi or mobile hotspot), even when remote support is accessible (C), scanners usually wait for a sonographer visit (O), because remote troubleshooting feels like an added burden in an already busy workflow (M).	"Again, a lot of time was spent gaining wifi access and uploading studies" [SR1].	"[If upload issues] I'm going to have to message somebody and have to talk to somebody and it's just going to take time" [GP4]. "No scans sent from this site since Jan 24 (6 months) due to unable to access internet" [OFN2]. "The internet remains a huge barrier. A lot of time was spent [by me, cardiac sonographer] checking connections and checking uploading was happening" [SR3].	NA	Street-level bureaucracy theory[139]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
33	P1.42, P2.89	When FNCHW and nurse scanners don't receive clear confirmation that scans have uploaded and will be reviewed by experts (C), they may start doubting whether the process will improve care (M), so they could stop scanning (O).	"I feel like my scans go into the abyss, how do I get results?" [N4]. "Currently, without being able to upload the images it makes us frightened to scan because if we find any problem such as regurgitation, we can't go any further. We can only do half the process" [OFN3, quoting FNCHW]. "Trainees here said they are scared to take images because if it can't be uploaded (and thus reviewed) they feel bad taking the imaging in case it is a positive scan and it goes nowhere" [OFN1].	"I was concerned that somebody wasn't looking at one that I had done with you. And so that caused me anxiety" [N1]. "It's more about whether or not scanning is something useful and good for them to do, for their patients, who they are very motivated to help and care for... I think a big part of us getting this right is finding ways to make sure that when people get scanned, this results in a useful result that is good for the patient and the team looking after them. Having good internet will be a big game changer" [OFN3]. "[Team member 1] It clearly makes the non-experts nervous if they aren't certain the scans will be seen and reported on. They worry they will miss something. [Team member 3]: And so stops them scanning" [OFN3]. "Also I know one of the reasons [for low scan numbers] is because there are scans done from two months ago that we have been chasing results that we haven't got back to them. This is issue on our end that would definitely be impacting. I know I would stop scanning because what I tell people about it being looked at by a cardiologist and results in a few days isn't being followed through" [OFN3].	NA	Street-level bureaucracy theory[139]

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
34	P2.104	When reviewers have less experience with RHD or handheld image interpretation and have borderline cases without clinical context (C), they may feel uncertain about some interpretations (M), so they may seek second opinions before reporting (O).	NA	“It probably is a lot quicker for them, but certainly myself and other reviewers that don’t do it as you know, we’ve used to full studies on not on, like proper machines, not the handheld ones” [C4]. “I think for people like [another cardiologist] and I though, we would often talk about image quality and send them to each other to say what would you call this? What would you call this?... we’re happy to say like, are we even qualified to be doing this? Can we do some [test] what you tell us because like I said, neither of us think this is a small thing that oh, you know, just get whoever can do it. Yeah, that’s not, you need people that understand the context, which [this other cardiologist] and I did. Yeah, but that’s probably why that weighs a bit heavy on us” [C4]. “It feels quite burdensome to me because I feel like the, getting it wrong is a disaster, like missing something bad” [C4]. “If they’re all normal, it’s quicker, or if the image quality is OK, or if the image quality is just terrible, that’s a quick one. You know? That’s just. Yeah, yeah, yeah. It’s those borderline ones” [C4]. “I do think that there are probably people like [cardiologists with more experience with RHD], who probably tear through it really quickly. Sometimes I can do that, other times it takes me longer, but I accept that’s just less experience. That’s how it works with imaging. It’s like when you start reporting anything” [C4].	NA	NA

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Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
35	P2.98	When busy cardiologists receive timely notifications that scans have been uploaded for review (C), they are more likely to review the images within the desired timeframe (O), because the reminder brings the task to their attention effortlessly, without them needing to remember to check the portal amid competing priorities (M).	NA	"We now get emailed links to which cases ours to review. I found that easier to incorporate" [C3]. "We get notification by email that there is a scan to report, and a separate email comes through for each scan. And I think that's actually good, because even though that doesn't mean you can necessarily jump straight on and do the reporting that email sits there as you know, as a flag or reminder that you know that there are scans to report" [C2]. "I think sending the reminder emails is really good. Just to remind you" [C4]. "When we're sort of constantly prioritising competing demands, I think, particularly before the reminder emails started coming that it was a bit too easy to forget to go onto the site, you know, for days, not usually weeks" [C2]. "I know I'm [X] morning" [C1]. "It does [help]. It's clear then whose scans are yours [to review]" [C4].	The median time from upload to review improved from 16 days (IQR width: 49) pre-email notifications to 6 days (IQR width: 19). Additionally, the proportion of scans reviewed within the protocol target of 48 hours increased from 22.2% to 41.6%.	Invisible work theory[254]

Table continued from previous page

Final ID	Draft IDs	CMOC	Phase 1	Phase 2	Phase 3	Substantive theories
36	P2.97	When cardiologists are placed on a review roster (C), they are more likely to review the images within the desired timeframe (O), because the roster clarifies who is accountable for reviews during that period (M).	NA	“When you open, you’ll see the image there, but it’s got to download each one to play, and so to get to play can take take, you know, get a lot of time. But it feels like quite a while longer. Longer than I’m used to in my own practice. Our systems can be slow at times as well, but it’s certainly very different to our systems in the hospital. And again, if you’ve got, if you’ve got 5 to 6 studies that’s fine, but if you’re looking at a large volume of studies that you know adds a lot to the time” [C1]. “A reminder e-mail which is good as well but...the onus is still on you to look at the study list and check the day...I’m like looking at my calendar, what date was Friday, you know? ‘Oh it’s this’. And looking at the time that seems like such a small thing, but again, like you probably want to make it more straightforward” [C4]. “I find [the image platform] how it’s set up cumbersome and time consuming, I think that could be slicker” [C1].	NA	NA
37	P2.102	When the reviewing system depends on cardiologists volunteering their time and they encounter friction in the process (e.g. clunky software, extra microtasks, or miscommunications) (C), they may disengage from the programme (O), because the optional, unpaid work becomes more burdensome than anticipated (M).	NA	“A couple of weeks later when we got this e-mail saying you have to do these [reviews], that probably didn’t go down super well, because we already feel like we’re doing that for free anyway and that’s the whole thing you’ve got these people who don’t have much time and normally get paid pretty well for things, that are now giving up free time, and then to kind of say [you must submit] adds guilt given we’re doing more work without any pleasure or anything was just like, yeah... it did not feel great” [C4].	NA	NA

References prefixed with ‘FG’ denote focus group data. All others are drawn from interviews. Brackets denote a different staff member of same cadre and site e.g. FNCHW3(2). GPO = GP–obstetrician, from the regional hospital NEARER SCAN study site who were invited to participate in one extended recruitment focus group (Chapter 2). C = cardiologist, NA = no relevant data / theory identified.

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