Transdisciplinary stakeholder understandings of antimicrobial resistance: An integrative approach in Aotearoa New Zealand

Sarah Mitchell Alexandra Macmillan,* Kate C Morgaine Patricia Priest

Department of Preventive and Social Medicine, University of Otago, New Zealand

Submitted: 13 February 2023; Revision requested: 21 August 2023; Accepted: 5 September 2023

Abstract

Objective: Antimicrobial resistance (AMR) is a complex public health issue, with a range of influences across human, animal, and environmental health. Given the complexity of the problem, the diversity of stakeholders, and the failure of current policies to curb AMR worldwide, integrative approaches are needed to identify effective actions. Underpinned by systems thinking and One Health principles, this qualitative study explored how diverse AMR experts in Aotearoa New Zealand perceive the main drivers and effects of AMR.

Methods: Semi-structured interviews with clinical, academic, policy, community, and industry representatives were designed to elicit mental models of the causes and outcomes of AMR across dimensions.

Results: Thematic analysis revealed contrasting understandings of AMR causes across four domains: food-producing animals (livestock), healthcare, community, and environment. AMR was often framed as a problem of individual behaviour, despite many implicit references to underlying structural economic influences. The politics of collaboration was a further major underlying theme. The interviews highlighted fundamental connections between AMR and other complex issues, including poverty and environmental pollution.

Implications for public health: This study brings together the understandings of AMR of transdisciplinary stakeholders, providing some immediate insights for policy makers and setting the foundation for developing a collaborative system model of AMR as a basis for decision-making.

Key words: antimicrobial resistance, antibiotic resistance, New Zealand, qualitative, stakeholders, one health

Introduction

Antimicrobial resistance (AMR) is a serious threat to global health,[1] undermining progress towards the Sustainable Development Goals.[2] While AMR is often characterised as a biological phenomenon, its drivers are also social, cultural, political, and economic, requiring more than technical solutions.[3] Many factors have been implicated in the emergence and transmission of AMR, including misuse of antibiotics for humans and animals, poor infection prevention and control, inadequate investment in antibiotic development, international travel and trade, and antibiotic and other environmental pollution.[4,5]

Aotearoa New Zealand (Aotearoa NZ) is a high-income country with agricultural production as an important part of the economy. Antibiotic use in humans is high by international standards and AMR is emerging as a threat to health.[6] In 2015, community antibiotic consumption comprised a higher proportion of total human antibacterial consumption in Aotearoa NZ than in any other nation with data available.[7] Around half of people who visited their family physician (known as a general practioner, GP, in Aotearoa NZ) in 2018 were dispensed at least one systemic antibiotic.[8] However, antibiotic use in food animals is relatively low.[9] Antibiotics that are important to animal and human health require a veterinary prescription, and the New Zealand Veterinary Association's goal is that by 2030, Aotearoa NZ will not need antibiotics for the maintenance of animal health and wellness.[10]

Thus far, policies have failed to effectively address AMR globally,[11] including in Aotearoa NZ. The New Zealand Antimicrobial Resistance Action Plan was launched in 2017 and was developed collaboratively with stakeholders from across the human health, animal health, and agriculture sectors.[12] However, in 2021, clinicians warned that

*Correspondence to: Alexandra Macmillan, Department of Preventive and Social Medicine, University of Otago, Dunedin, New Zealand, 18 Frederick St, Dunedin, 9016, Aotearoa New Zealand. Tel.: +64 21 322 625.
e-mail: alex.macmillan@otago.ac.nz.

Aust NZ J Public Health. 2023; Online; https://doi.org/10.1016/j.anzjph.2023.100093

progress on the Action Plan has been poor, and "efforts remain fragmented, poorly coordinated and inadequate".[13]

Tackling the fundamental causes of AMR will require the coordinated action and combined expertise of many stakeholders,[11] who often have competing interests and understandings.[2] Effective policy making requires an appreciation of problem complexity[14] and an understanding of the perspectives of actors involved.[15] Most qualitative studies about AMR have focussed on one or two groups of stakeholders, such as patients,[16] physicians,[17,18] dentists,[19] veterinarians,[20] and farmers.[21] Studies comparing understandings of AMR between multiple different stakeholders include quantitative survey-based approaches[22,23] and some qualitative studies.[17,24,25]

Many experts have called for integrated approaches that encourage cross-sectoral collaboration, embrace complexity, promote a systems view, and emphasise the underlying social, ecological, political, and economic contexts.[1,3,4,26] Several national and international AMR action plans emphasise 'One Health' approaches to AMR, actively considering interactions between human, animal, and environmental health.[11]

However, the complex interactions and relative contributions of the sources and transmission pathways of AMR are poorly understood,[4,5,11] with insufficient evidence to underpin effective policies.[27] The need for more studies on the systems of interactions between social, economic, cultural, and political drivers of AMR is increasingly clear.[28–30]

System dynamics (SD) modelling is a systems thinking methodology and has been identified as a suitable approach for dealing with and addressing the dynamic complexity that characterises many public health issues.[31] SD modelling has four methodological principles: the changing interaction of many variables over time is the main driver of behaviour in complex systems; this dynamic interaction is characterised by reinforcing and balancing feedback loops; the accumulation of "stocks" is also important—that could include people, information, or material resources; and the pattern of cause-and-effect relationships may change over time, creating tensions between short- and long-term policy effects.

SD modelling processes involve eliciting stakeholder implicit understandings (often called "mental models") and developing causal diagrams and policy-oriented simulation models, so that alternative policies and scenarios can be tested systematically.[31] Participatory SD (pSD) modelling is transdisciplinary and facilitates knowledge sharing, knowledge generation, negotiation, and planning,[32] by allowing integration of various types of information.[33] The process of model building helps stakeholders to clarify their own implicit understandings of the problem, appreciate the perspectives of others, and build an enhanced shared understanding of the system to build towards consensus about action.[33]

This study was the first stage of a pSD modelling approach to informing AMR policy in Aotearoa NZ and aimed to explore with diverse stakeholders with expertise in AMR in Aotearoa NZ, their mental models of the main drivers, and effects of AMR across the One Health sectors of human, animal, and environmental health.

Methods

Our study was undertaken within the theoretical framework of pSD, so it aimed to elicit mental models of cause-and-effect relationships. We built on qualitative methodological foundations and more recent debate about the theoretical underpinnings of One Health.[27] We adopted a critical realist position, using qualitative research as a way to develop structural understandings of the socio-technical system of AMR; elicit critical themes about meaning, assumptions, and power; and investigate the implicit roots of AMR. We used both deductive and inductive analytic approaches to achieve these aims. Our criticality emerges from values related to equity and justice, particularly by income and ethnicity, and human flourishing within ecosystem limits. These values and principles informed our methods and analysis.

We used an *a priori* sampling framework to target the One Health dimensions of human, animal, and environmental health, as well as including transdisciplinary participants (with scientific, policy, industry, and community knowledges, Table 1). We aimed for a national sample of 20–30 people. Our initial sample drew on our knowledge of those working in the field of AMR, advice from others knowledgeable about AMR, and from considering the list of stakeholders involved in the multidisciplinary Aotearoa NZ AMR Working Group.[12] It was also influenced by Majowicz et al.'s identification of 'non-traditional' stakeholders who could be involved in mitigation of AMR.[29] Snowball sampling was also applied by asking interviewees for recommendations of further participants.

Potential participants were invited to take part by email and telephone. In-depth, semi-structured interviews were carried out by SM between April and August 2018. Almost all were face-to-face, with one interview conducted via Skype. In some cases, two people were interviewed together, when they were from the same organisation and expressed a preference to be interviewed together.

Table 1: Question guidelines for semi-structured interviews.

Context setting	• Can you tell me about your role in your organisation and how it relates to AMR? • Do you have other professional roles that relate to AMR? • What interested you about this project?
Changes to AMR over time, projections	• What do you think has been happening to AMR over time? (e.g. has it been increasing in a linear way? Or exponentially?) • How do you see it progressing in the future if we continue business as usual? • What would be the best-case scenario if effective action is taken?
Causes and effects of AMR	• **Main question: what do you think are the main causes of AMR in New Zealand?** *Prompts* - What do you think causes that/is underlying that? - What effect/consequences does that have? - How does it relate to/could it be related to… • **Main question: what are the effects of AMR in New Zealand?** *Prompts* - Short-term and long-term effects - How long does it take… - Who, what, when, and how…. - Actors, resources, information flow, imperatives - Who carries the cost of these effects? Does anyone benefit? - How might this affect equity?
Final questions	• Is there anything else you think I need to know? • What would be your top three policy recommendations to help reduce AMR in New Zealand?

As the first step in developing an SD model, the interview questions and prompts were designed to elicit understandings of AMR trends over time. The opening questions explored perceptions of past trends and possible future scenarios. Proximal and distal influences and consequences were explored with the aid of prompting questions. Table 1 outlines the main areas of questioning for the semi-structured interviews. Interviews were audio recorded and transcribed 'intelligent verbatim'. Transcripts were sent to participants for optional checking and approval.

A two-phase process of thematic analysis was used to identify and analyse patterns within the data. The initial stage was deductive, guided by our aim to elicit the causes and effects of AMR in the context of our theoretical perspective, and identify overarching sectors that would help to organise causal diagrams. This involved an iterative and active process including familiarisation with the data, coding of subthemes, and several rounds of reviewing and defining themes. We have labelled these deductive themes 'sector categories' to distinguish them from the inductive analysis.

The second phase comprised a critical inductive thematic analysis to elicit implicit assumptions and ideas about the AMR system. We have labelled these 'conceptual themes'. This inductive thematic analysis was guided by Braun and Clarke's (2006) approach to interpretative analysis.[34] All coding was completed by SM, with input from the other authors. A report of the main findings was provided to participants upon completion of the research.

Results

Twenty-seven in-depth interviews were carried out with 31 stakeholders. Most interviews were about an hour in length but ranged from 30–90 minutes. Table 2 shows how participants fitted the sampling frame, with those having several areas of expertise listed in the category they were primarily recruited to address. Some categories had greater numbers of participants due to category complexity. Fewest stakeholders were identified in the environment domain. Fifteen of the participants were women.

Table 2: Participants and how they fit the sampling frame.

	Human	Animal	Environment
Academic/ research	Surveillance microbiologist Clinical microbiologist	Veterinary microbiology academic Veterinary epidemiologist	Ecologist Systematics researcher Microbial geneticist Pharmacist
Policy	Ministry of Health PHARMAC	Ministry for Primary Industries NZ Veterinary Association	Politician
Community	Consumer advisor		
Industry	Medicines NZ Pharmaceutical company	AGCARM PIANZ Federated farmers	Horticulture advisor
Clinical	IPC nurse Infectious disease physician General Practitioner Antimicrobial stewardship pharmacist Clinical microbiologist	Rural vet	Wildlife veterinarian

PHARMAC = Pharmaceutical Management Agency (government agency that funds access to medicines in NZ), AGCARM = NZ Association for Animal Health and Crop Protection, PIANZ = Poultry Industry Association of NZ, IPC = infection prevention and control.

All interviewees agreed that AMR has been increasing over time, with varied ideas about the pattern of growth (e.g. linear, exponential, sigmoid). Several felt unable to comment on a possible pattern, due to limited data availability, changing surveillance methods, and potential pattern variability by microbe. Many thought the best possible scenario would be to slow the rate of increase in AMR. Some hoped that with enough effective action, we may see a plateau in resistance levels. Others expressed concern that a tipping point has been passed for being able to achieve a change in the growth trajectory.

Most participants saw AMR as a highly complex issue with multiple influences relating to human, animal, and environmental health, but there was no consensus about what should be the policy focus in Aotearoa NZ. The main causal relationships discussed by participants were coded into four sector categories: food-producing animals, healthcare, community, and environment. These are described below, with each quote attributed to a participant using a code (e.g. P22).

Antibiotic use and resistance in food-producing animals

Many interviewees raised the issue of antibiotic use in livestock to improve health and welfare and to enhance productivity, but any implications for human health were contested. Some felt that resistance transmission from livestock to humans is likely to contribute to a significant portion of AMR in humans, whilst others (including some experts from human health) thought this transmission is unlikely, particularly in Aotearoa NZ:

> *"Obviously we use a lot of antibiotics for drying off cows and things like that, but how much that flows on to contributing to AMR in humans, I'm far from convinced. We also use lower amounts in New Zealand agriculture, so I think to point the finger at the agricultural industry would be wrong... But I don't think we really have a good handle on it."* (P2)

The role of agricultural intensification in determining AMR was a source of further contestation. Several participants saw intensity of animal agriculture as a crucial determinant of antibiotic use (by increasing the likelihood of disease transmission). On the other hand, some interviewees argued that intensive farming systems allow for increased control over the animals' environment (e.g. better management of effluent), reducing the spread of disease and therefore reducing the need for antibiotics. Some suggested the economic importance of animal agriculture for Aotearoa NZ was a barrier to reducing antibiotic use, while others emphasised the country's already low use of antibiotics in agriculture by world standards.

AMR in healthcare

Many of the described influences on AMR were in human healthcare settings. Influences on antibiotic prescription and stewardship in human health, and factors affecting patient use, were widely discussed. Patient demands and expectation of getting "value" from consultations, time constraints, a desire to avoid complicated interactions, and pressure to avoid hospital admissions were all considered to contribute to antibiotic prescriptions by primary care physicians. Anxiety about infectious disease amongst both the public

and prescribers was also thought to increase antibiotic prescription and use:

> *"I think also fear drives a lot of the expectation from the public … But I don't think that's just the public. I think there's a fear in prescribers that they'll miss something important."* (P3)

Hospital prescribing in Aotearoa NZ was considered to be well managed. Hospital prescribers have access to expert advice and the ability to monitor patient adherence closely or change antibiotics following susceptibility testing. Nonetheless, hospitals and rest homes were frequently identified as 'hotspots' of AMR due to the large numbers of vulnerable people in close proximity, where antibiotic use is high.

In hospitals, standards of infection prevention and control (IPC) were seen as crucial to prevent transmission of infection. Staff commitment to IPC practices was thought to be affected by education and the simplicity of policies and procedures. Workload and access to facilities (e.g. for handwashing) were also considered influential on compliance with policies, as were the relationship between infection control and clinical staff, and building design.

Individual patient understandings of AMR and antibiotic guidance, their experience of side effects, and the cultural inclusiveness of antibiotic-related messages were all considered to influence knowledge and adherence to prescriptions.

AMR in the community

Inequitable community vulnerability to AMR was frequently linked to structural inequities (by income and ethnicity) in the social and environmental determinants of health, including poverty, housing quality, and access to healthcare. Further, it was noted that policies to reduce antibiotic use will have to ensure equity of antibiotic access is attained:

> *"There are things we've got to be careful about as we try to address AMR; one is that as we try to reduce antimicrobial use, we don't reduce access to legitimate antimicrobial use among vulnerable populations, and that is a real risk."* (P28)

Interviewees generally thought that community antibiotic use is very high in Aotearoa NZ, and some identified this as a key determinant of the spread of AMR, while acknowledging the underlying drivers of Aotearoa NZ's relatively high prevalence of infectious disease.

The potential for transfer of resistant organisms from companion animals to humans in the community was also highlighted. Pressure from pet owners to prescribe antibiotics, and the fact that culturing and antibiotic susceptibility testing is unaffordable for many pet owners, were said to affect veterinarians' antibiotic stewardship, and therefore, rates of resistance carriage by companion animals.

AMR and the environment

Several interviewees saw the environment as a vital but poorly understood aspect of the AMR system. Contamination of waterways with pharmaceutical waste in antibiotic-manufacturing countries with limited regulation was considered an important contributor to global AMR. Participants also discussed how unchanged antibiotic excretion contaminates residential, hospital, and agricultural wastewater. Livestock farming was often identified as a likely source of antibiotic pollution in Aotearoa NZ. Overall, the growing pool of resistance elements in environmental bacteria was thought to increase the risk of transfer of resistance genes to human pathogens. Some postulated that crops and wild foods, or fresh and drinking water, may be contaminated with antibiotics or resistant bacteria or that migratory birds may transport and disperse antibiotic resistance genes.

Participants also mentioned everyday chemicals that may co-select for resistance genes, ranging from herbicides, pesticides, and cleaners to personal care products. Several warned about complacency regarding widespread chemical use, including the role of advertising in heightening concern about household "germs", resulting in the extensive use of antibacterial cleaners.

The inductive thematic analysis drew out three interlinked conceptual themes:

The role of economic influences

A pervasive underpinning theme was about macro-economic influences on AMR. This was often implicit, including assumptions about healthcare as a business, such as references to patient expectation of 'value' for doctor's appointments (including receiving a consumer product), and pressure on general practitioners to prevent hospital admissions as a cost-saving measure (leading to lower thresholds for antibiotic prescribing).

Participants commonly proposed that antibiotics are used in animal agriculture for economic reasons of improving productivity and profitability, though some suggested that over time, increasing AMR would reduce the economic appeal of antibiotic use. Conversely, minimising antibiotic use was perceived as a defensive marketing strategy, responding to consumer demand.

The profit-based economic model of pharmaceutical companies was frequently alluded to as a barrier to the development of new antibiotics:

> *"Most antibiotics are subsidised and cheap, you only pay a few dollars for them, and so from a purely financial point of view from a pharmaceutical company, it doesn't make a lot of sense to go to considerable effort…"* (P22) .

Occasionally, this was linked more explicitly with a general concern about privatisation of public goods, including resulting perverse incentives:

> *"There are probably no other medicines that we have so actively colluded to undermine than antibiotics…I don't think it's an accident that antibiotics have lived the zenith of their existence also during a time when the market and our ideological belief in market forces and privatisation of public goods has also reached its zenith."* (P23)

On the other hand, others gave economic reasons that pharmaceutical companies might refrain from promoting antibiotic use. Overuse undermines the longevity of the product, and some pharmaceutical companies may be concerned about their reputation if they were to push prescribing in the face of worsening AMR.

Macro-economic influences were also implicit in proposed relationships between globalisation and AMR. Many stressed that antibiotic practices and sanitation in other countries influences AMR in Aotearoa NZ, through international travel (including healthcare tourism) and globalisation of trade. Several thought many resistant infections seen in Aotearoa NZ are likely to have originated overseas. This globalised trade and investment context was also behind observations about antibiotic manufacturing occurring in low- and middle-income countries with poor environmental regulations.

The role of macro-economics was also evident in discussions of income and housing system inequities, and the pathway from these structural inequities to inequitable infectious disease exposure and outcomes by income and ethnicity, since both are consequences of macro-economic policy.

In addition, lack of political prioritisation for funding AMR action was frequently said to be a problem in Aotearoa NZ, perhaps reflecting ongoing attempts to reduce healthcare spending in a low-tax, deregulated government context:

> *"The resources to do all that work aren't there. There's no funding. So the AMR group comes up with all these actions, and it's like how are you going to pay for it?"* (P8)

Overall, macro-economics appeared to be a pervasive influence on AMR and a barrier preventing effective action on AMR.

Individualising the problem

Antithetical to these largely unarticulated acknowledgements of structural economic drivers was a much more explicit framing of AMR, as primarily a problem of individual behaviour and responsibility. This was exemplified by frequent references to the need for more judicious antibiotic prescription and use by a range of groups, including patients, doctors, vets, farmers, and the wider public. For example,

> *".. I think that we're not that strict on the charting and the distribution of antibiotics, so I think there's clinician responsibility about making sure that they chart the correct antibiotic at the right time and the right dose."* (P1)

The need for better staff adherence to IPC practices in hospitals and rest homes was also a feature of this framing. Attribution of the problem to individual behaviour was accompanied by calls for more education or training. Commonly, participants emphasised the importance of infection prevention and control practices for hospital staff, or the need for more education of the public about appropriate antibiotic use and how AMR works, for example, in relation to hand hygiene:

> *"And how we educate both health professionals and the public to take some responsibility themselves."* (P4)

The politics of collaboration

Collaboration between different stakeholders was frequently discussed as a contributing factor to how well we can address AMR. Siloed or competitive thinking was seen to be a problem both between and within disciplines:

> *"Everyone wants to do good stuff, but they don't want to do it with anyone else… We're all doing individual great stuff and not sharing ... Not like the bacteria, we don't share good ideas."* (P8)

Some stakeholders felt blamed or attacked by others, inhibiting collaboration. Externalising responsibility can lead to strident calls for action by other groups, making others less inclined to collaborate, and undermining effective action. Some parties felt *"if you're not round the table, you're on the menu"* (P11), indicating that trust between stakeholders is important.

Many interviewees recognised the importance of collaboration in tackling AMR. Several specifically highlighted the need for a One Health approach. Some interviewees thought that communication and collaboration is starting to improve in Aotearoa NZ, for example, via an existing multi-disciplinary AMR working group. Better communication with other sectors had led them to better appreciate the reasons for those sectors' antibiotic use.

Discussion

This qualitative study synthesises the qualitative understandings of AMR held by academic, clinical, industry, community, and policy actors across human, animal, and environmental domains.

The interviews highlighted a lack of good AMR surveillance data, and connections between AMR and other complex issues, including pharmaceutical funding models, globalisation, livestock-rearing practices, poverty and inequality, health system pressures, and environmental pollution. While many of the current strategies for addressing AMR focus on technological and biomedical solutions, this study emphasises that rising levels of AMR are a fundamentally socio-economic and political problem with upstream influences.

Inductive analysis resulted in three underlying major conceptual themes, which superficially appear to be dissonant, yet resolve into inter-related aspects of the current political economy: the dominant global macro-economic model; a tendency towards explicitly focussing on individual responsibility; and the political economy of collaboration between diverse stakeholders within the current model of public service organisations. Although many participants repeated common recommendations about fostering collaboration and understanding between disciplines, the fundamental drivers of competition between them and the structural drivers of individual choices were generally left unquestioned. Further work to develop better understanding by stakeholders and policymakers of the relationship between structural factors and individual behaviours may be necessary to reduce externalisation of blame by stakeholders.

The sector categories and conceptual themes identified in this study are consistent with those reported by Lambraki et al.,[28] who held focus groups with human, animal, and agricultural stakeholders in the European food system to refine a Canada-based causal loop diagram. They grouped findings into "categories" (including agriculture, trade, public health, environment), "themes" (including AMU and AMR spread, economic and agricultural practices, consumer choice, health and social care systems) and "overarching factors" (including collaboration, climate change, leadership).

Previous work has found that different actors frame AMR in different ways, including as a healthcare, development, innovation, or a security issue, and more recently, a One Health issue.[26,35] Many of these discourses were reflected in the interviews for this study. Similar to the findings of Golding et al. (2019), several interviewees in this study did not consider AMR an important issue in livestock but were concerned that animal welfare may be compromised in future due to increases in AMR or restrictions on antibiotic use.

Unlike some prior research that found a tendency for actors to attribute more weight to the actions of other individuals or sectors in causing AMR,[22,23] we found that while human health participants were more likely to consider antibiotic use in livestock to be a risk to human health than stakeholders from animal health, both agreed that evidence of transmission between food animals and humans is limited and unlikely to be significant in AotearoaNZ. While limited

externalisation of blame occurred, a larger barrier to collaboration identified in this study was a perception of being blamed by others.

The strengths of this study are the underpinning integrative approaches of One Health and systems thinking, which are increasingly called for.[5,26] There were more interviewees in the human health and clinical categories because they included a wide range of relevant roles.

Limitations include gaps in representation, particularly in the community sector, and the environment dimension. The latter may reflect that concern about AMR in the environment is relatively recent and a lack of attention to the environment in One Health research more generally.

The exploration of cause-and-effect understandings of AMR by transdisciplinary stakeholders in this research forms the basis for the development of a qualitative systems understanding of AMR to inform policy making. Our findings already suggest that a focus on the political economy of AMR in national AMR action plans could assist with collaboration between sectors responsible by reducing tensions between sectors, while increased investment in the ecology and environmental science of AMR is also needed. Our findings suggest that addressing AMR will also require synergistic action on the social determinants of health.

Conclusion

This study sought to elicit the mental models of cause-and-effect relationships in the AMR system, of key stakeholders in A-NZ. The domains of livestock, healthcare, community, and the environment were all considered important. Increased investment in surveillance and in understanding the ecology and environmental science of AMR is also needed. There was a contrast between underpinning references to economic influences on AMR versus attribution of the problem to individual behaviour. Political prioritisation of AMR and fostering further collaboration could facilitate better progress on the action plan. Addressing AMR will also require synergistic action on the social determinants of health. The consistency of our findings with those from Europe suggests that the drivers of AMR in Aotearoa NZ may be similar to those in other high-income countries.

To further progress this research to a pSD model, next steps would involve workshops to confirm and strengthen a shared qualitative system dynamics causal model derived from the interviews, followed by conversion to a quantitative model which incorporates data, tests the causal theories proposed by stakeholders, and allows simulation of possible policy interventions. The ultimate aim is to identify key areas of the system that may be leveraged to make the most difference to the problem of AMR.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institution and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Ethics approval for this project was obtained from the University of Otago Human Ethics Committee (Category B, Ethics Committee reference number D18/077).

Funding

This study was funded by a University of Otago, Aotearoa NZ postgraduate research scholarship.

Conflicts of interest

The authors have no competing interests to declare.

Acknowledgements

The authors thank Dr Jeffrey Foote for providing helpful advice in the design of the study.

Author ORCIDs

Alexandra Macmillan https://orcid.org/0000-0001-8070-3280

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