Improving Access to Diagnostic Testing for Rural Communities in Aotearoa/New Zealand.

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Abstract

Aim

To improve access to computed tomography (CT), point-of-care laboratory testing (POC testing), point-of-care ultrasound (POCUS) and cardiac exercise testing (ETT) for rural populations.

Methods

1. Utilisation rates were used to quantify improvements in access to services for rural populations.
2. Impact on diagnostic certainty and patient disposition was evaluated with a pre- and post-test questionnaire.
3. A specialist panel assessed the quality, safety and clinical impact of POCUS.
4. Qualitative interviews highlighted the benefits and challenges of the rural diagnostic services.
5. Economic evaluations of the rural diagnostic services were undertaken using cost minimisation analyses.

Findings

Geographic disparities in access to CT were overcome when a rural service was established. POC testing and POCUS increased diagnostic certainty, reduced admissions and inter-hospital transfers (POCUS by 8%). For some patients (4% POC testing, 5% POCUS) the test prompted urgent inter-hospital transfer.

POCUS benefited 71% of patients, 22% significantly. Despite the overall benefits, significant error rates were identified. The quality of 17% of the images was inadequate and 7% were incorrectly interpreted. Ten percent of times, the POCUS findings were different to those obtained by formal imaging or the final diagnosis. The error rates were mitigated by incorporating POCUS into a full clinical assessment.

Savings in the form of reduced inter-hospital transfers and hospital admissions (POC testing) outweighed the costs of the service. In the ETT study, the costs of rural ETT compared favourably to the costs of an urban service.

Qualitative findings highlighted the impact of travelling large distances to access health care for elderly Māori in particular, and the improved job satisfaction for rural health professionals as a result of greater diagnostic certainty.

Conclusions

The wider adoption of rural CT, POC testing, POCUS and ETT, are cost effective ways of improving diagnostic certainty, reducing inter-hospital transfers and supporting rural practice. Learning and maintaining POCUS skills is challenging and demands recognised scopes of practice and standards for training, credentialing and quality assurance.

Rural Māori may be particularly vulnerable to the impacts of having to travel to access healthcare, and may have the most to gain from the provision of as many health services (including diagnostic tests) as possible in their local communities.

Dedication

To Arlene

Acknowledgements

Ngaire Kerse and Ross Lawrenson for supervision. The co-investigators on all the studies in this thesis but especially Kati Blattner. The Hokianga and Central Otago communities.

The following lines are borrowed from the Philosophy and Values of Hauora Hokianga, Hokianga Health Enterprise Trust.

Papal encyclical, Quadragesimo Anno, in 1941:

"It is an injustice, a grave evil and a disturbance of right order for a larger and higher organisation to arrogate to itself functions which can be performed more efficiently by smaller and lower bodies."

In the words of popular writer and business columnist, Charles Handy: *"stealing people's responsibility is wrong"*

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Abbreviations

AAA	Abdominal aortic aneurysm
ACC	Accident Compensation Corporation
BAT	Blunt abdominal trauma
CABG	Coronary artery bypass grafting
CT	Computed tomography
DHB	District Health Board
ED	Emergency department
ETT	Cardiac exercise tolerance testing
GCS	Glasgow Coma Scale
IHD	Ischaemic heart disease
IVC	Inferior vena cava
JVP	Jugular venous pressure
MoH	Ministry of Health
MRT	Medical Radiation Technologist
NDHB	Northland District Health Board
NFLS	No flow limiting stenosis, with respect to coronary angiography
NHC	National Health Committee
PCI	Percutaneous coronary intervention
POC	Point-of-care
POC testing	Point-of-care laboratory testing
POCUS	Point-of-care ultrasound
RNZCGP	Royal New Zealand College of General Practitioners
SDHB	Southland District Health Board

Chapter 1: Introduction

The economic wellbeing of Aotearoa New Zealand (NZ) relies on agriculture, horticulture, forestry and tourism. We are a trading nation and these rural industries account for six of our seven top export earners. (1) Despite the disproportionate growth of major urban centres in recent decades, our identity is still inextricably linked to our rural heritage and we remain at heart a ‘rural country’. Maintaining the health of our rural communities is important for the wellbeing of the entire nation.

Health does not wholly rely on health services. Socioeconomic determinants of health are well recognised, and in NZ socioeconomic and ethnic-related disparities are described. (2-4) This thesis, however, focuses on how health services can assist in health improvement in rural areas, with specific reference to the impact of diagnostic health technology.

There is no shortage of challenges to delivering high quality healthcare to rural communities. The problems in educating, recruiting and retaining an appropriately skilled medical workforce are the subject of ongoing discourse amongst those involved in the sector. There has also been debate around the most appropriate models of primary healthcare services in rural areas. There has been less discussion about individual secondary care services, and in particular what secondary diagnostic services can be safely and sustainably delivered in rural communities in the modern era.

There is no doubt that medicine is becoming more complex as the range of often highly technical tests and treatments grows. In response, healthcare is becoming increasingly specialised. This is particularly so for secondary care where the generalist specialist is being replaced by teams of subspecialists. (5) Subspecialisation is a potent driver for centralising services. The complexity of health technology (and consequent capital and operating costs) is a further driver. Many medical technologies are now economically viable only in urban areas where high volumes reduce the unit costs to acceptable levels. (6) This adds considerably to the challenges of delivering healthcare to rural communities and runs the risk of further exacerbating rural vs. urban inequities in access to services and the consequential contribution to inequities in health outcomes faced by rural populations.

Paradoxically, the same development in medical technology that is driving centralisation increases the range of services that could potentially be provided in rural communities. This is because some technologies that were once the domain of specialists are becoming easier to operate, more portable and cheaper. The challenge then is to recognise and make the most of these opportunities when they arise. This is not straightforward. The forces that drive this process are relatively weak compared to those driving specialisation and centralisation. Urban specialists are not naturally inclined to devolve services and skills they consider their domain to generalist doctors working in rural areas. (7)

The introduction to this thesis explores what is known about the impact an increasing reliance on technology and the centralisation of modern medicine is having on the ability of rural New Zealanders (NZers) to equitably access health services, and on their health outcomes. The studies that comprise the main body of the thesis are, however, ‘solution’ rather than ‘problem’ based. They identify a number of traditionally urban-based diagnostic services that, because of evolving technology, now have the potential to be delivered in rural areas. To justify the uptake of these services it is necessary to show that they are meeting a genuine health need, they can be safely provided in rural areas at a standard comparable to an urban service, and they are cost-effective investments of public health resources. The studies in this thesis seek to evaluate these services with respect to these criteria. In doing so, the thesis aims to increase the range of health services that are provided ‘close to home’ for rural NZers.

There is an additional body of personal research that provides relevant background to the thesis, but is not included in the main body. This research deals with the rural hospital generalist workforce, standards of care in rural hospitals, rural health inequities, and barriers to accessing secondary care for rural communities. This body of work is summarised in the introduction and the publications are provided in an appendix that sits separate to the body of the thesis.

International rural vs. urban health disparities

In 2018, the World Organization of Family Doctors (WONCA) reaffirmed the “goal of health for all rural people” in the *Delhi Declaration 2018: Alma Ata* revisited. (8) The Declaration notes the persistence of rural vs. urban health disparities. Worldwide, 52% of people living in rural communities are not covered by basic healthcare compared to 22% of people living in towns and cities.

Inequities in health outcomes have been demonstrated for rural populations in countries similar to NZ. (9 -13) For example, people living in remote and very remote parts of Australia have mortality rates that are 1.4 times that of people living in the cities. In Australia (and Canada), the gradient of worsening health outcomes associated with increasing rurality that rural health researchers have demonstrated, is now accepted by government, and has become an important driver for targeted rural health policy. The Australian National Strategic Framework for Rural and Remote Health, for example, acknowledges that rural people face a range of health disparities compared to their urban compatriots that include: higher mortality and reduced life expectancy; higher rates of accidents and chronic disease; poorer dental health; and poorer antenatal and postnatal health. (14) The overarching vision of the Framework is to overcome these disparities and improve health outcomes for rural Australians. There has been a recent call for this strategy to be updated. (15)

The extent to which rurality in itself is responsible for the health disadvantage faced by rural populations is less clear. A review of the international literature on rural vs. urban health disparities in 2008 concluded that the principal impact of rurality on health was the exacerbation of other health determinants. (16) Aspects of the rural lifestyle, many of which are intertwined with socioeconomic status, may have some influence (these include rural occupations, risk taking and unhealthy behaviours). (16) However, most of the negative gradient in health status seen with increasing degrees of rurality can be explained by increasing socioeconomic deprivation and larger proportions of indigenous population (that also increase with rurality and remoteness). On reviewing the international literature, the NZ National Health Committee came to similar conclusions, namely that the variation in health status between rural and urban residents noted in Canada, Australia, Britain and America could be explained by socioeconomic factors and the proportion of indigenous people. (17) This might be expected. Rural residents with the means will be able to overcome any health disadvantage associated with rurality by investing money and 'social capital' in their health. However, those who are unable to make these investments face poorer access to services and risk poorer health outcomes as a consequence. This does not diminish the importance of rural health initiatives, but emphasises the importance of targeting those communities and populations with the greatest needs as a consequence of combinations of rurality, ethnicity and socioeconomic deprivation.

NZ is no different and, in order to understand rural vs. urban health disparities, it is necessary to understand how socioeconomic status and ethnicity vary across the rural-urban continuum. In NZ it is also necessary to understand the confusing array of urban-rural typologies that have been applied to our health and social data. It is surprising that the interaction of these factors has not previously been considered in our rural health literature. This forms important background to the thesis and a substantial part of the introduction chapter is therefore dedicated to exploring in detail what is currently known about rural-urban health disparities in NZ.

Rural vs. urban disparities in NZ

NZ Deprivation Index

The New Zealand Deprivation Index is an index of geographic deprivation constructed from Census data and based upon nine variables: telephone, benefit, unemployment, household income, car access, single parent family, no qualifications, home ownership, and overcrowding. (18) The index is applied at the meshblock level, which is the smallest area unit recognised by Statistics NZ. Level 10 meshblocks are the most deprived, and those on level one are the least deprived.

Urban-rural classifications in NZ

There is no internationally agreed definition of 'rural', (19) but the NZ situation appears to be particularly complex and confusing. We are aware of 17 different ways in which 'rural' has been classified in NZ health reports and research, including six different modifications of the current Statistics NZ urban-rural profile. Because of this confusion, and the important role typologies have on the way we interpret health data, I will explore in some depth how urban-rural classifications are used with NZ health research and policy.

Old Statistics NZ profile

From 1992 until 2004, Statistics NZ used the ‘urban area classification’ in Table 1 (referred to in this thesis as the *Old Statistics NZ profile*). Any town with a population of more than 1000 people was classified as urban. When this classification system was applied to the 2001 Census data, 12.8% of NZers were classified as ‘rural’. (20)

Table 1: Old Statistics NZ profile for urban-rural classification

Urban/rural classification	**Area Type**	**Definition**
Urban	Main urban	Towns and cities with a minimum population of 30,000 people
	Secondary urban	Towns with a population between 10,000 and 29,999 people
	Minor urban	Towns with a population between 1000 and 9,999 people
Rural	Rural centre	Population between 300 and 999 people
	True rural	Population less than 300 people

Source: Ministry of Health. Urban–Rural Health Comparisons: Key results of the 2002/03 New Zealand Health Survey.(20)

This classification was widely used until the mid-2000s and most NZ rural research published before then is based on it. This research includes the influential 2007 Ministry of Health (MoH) report *Urban–Rural Health Comparisons: Key results of the 2002/03 New Zealand Health Survey* (referred to in this thesis as the ‘MoH 2007 report’). (20)

Current Statistics NZ profile

Statistics NZ modified the urban area classification in 2003 creating the 'Urban/Rural Profile (experimental) Classification'. (21) Although the term 'experimental' has persisted, this classification has become the urban-rural profile used routinely by Statistics NZ, and other government agencies and researchers in NZ. This profile will be referred to as the *Current Statistics NZ Profile*.

Table 2: Current Statistics NZ profile

Urban/Rural Classification	**Area Types**	**% total NZ pop.**
Urban	Main urban areas	72
	Satellite urban areas	3.2
	Independent urban areas	10.9
Rural	Rural areas with high urban influence	3.1
	Rural areas with moderate urban influence	3.8
	Rural areas with low urban influence	5.5
	Highly rural / remote areas	1.6

Source: 'Rural Health, challenges of distance, opportunities for innovation' report. (17)
NZ=New Zealand

The *Old Statistics NZ profile* is based on the population size of a community. The important variable in the *Current Statistics NZ profile* is employment. It is a functional classification, reflecting geographic areas in which people live and work.

The main urban areas are the same as those in the *Old Statistics NZ profile*; i.e. Whangārei, Auckland, Hamilton, Tauranga, Rotorua, Gisborne, Napier-Hastings, New Plymouth, Whanganui, Palmerston North, Kāpiti, Wellington, Nelson, Christchurch, Dunedin and Invercargill. 'Satellite urban areas' are defined as urban areas (other than 'main urban areas') where more than 20% of the residents have a workplace in a main urban area. 'Independent urban areas’ are urban areas (other than ‘main urban areas’) where less than 20% of the residents work in a ‘main urban area’.

‘Independent urban areas’ have fewer connections with, and are less dependent on, a ‘main urban area’. Although the defining variable is employment, it is likely that independence will apply to other variables, such as health services. ‘Independent urban areas’ are the communities most New Zealanders would recognise as ‘rural towns’.

Consistent with international practice, rural areas are defined as the residual areas, i.e. those areas that are not urban. Again, the important variable in the rural index is employment. ‘Rural areas with high urban influence’, in particular, are a transition zone between ‘main urban areas’ and genuinely rural areas. A ‘significant proportion’ of residents in ‘rural areas with high urban influence’ will work in a main urban area. These are the rural landscapes within commuting distance of ‘major urban areas’.

National Health Committee urban-rural profile ‘NHC Profile’

A second important report on the health of rural NZers was undertaken in 2010 by the National Health Committee (NHC), *Rural Health: Challenges of Distance Opportunities for Innovation* (referred to in this thesis as the ‘NHC 2010 report’). In this report the NHC proposed a modification of the *Current Statistics NZ Profile.* The *NHC Profile* is the same as the *Current Statistics NZ Profile* with respect to area types, but different in that it classifies ‘independent urban areas’ as ‘rural’ and ‘rural areas of high urban influence’ as ‘urban’ (Table 3).

Table 3: National Health Committee urban rural profile (NHC Profile)

Urban/Rural Classification	**Area Types**	**% total NZ pop.**
Urban	Main urban areas	72
	Satellite urban areas	3.2
	Rural areas with high urban influence	3.1
Rural	Independent urban areas	10.9
	Rural areas with moderate urban influence	3.8
	Rural areas with low urban influence	5.5
	Highly rural / remote areas	1.6

Source: 'Rural Health, challenges of distance, opportunities for innovation' report (17)

When considering health, this is a logical adaption of the *Current Statistics NZ Profile*.

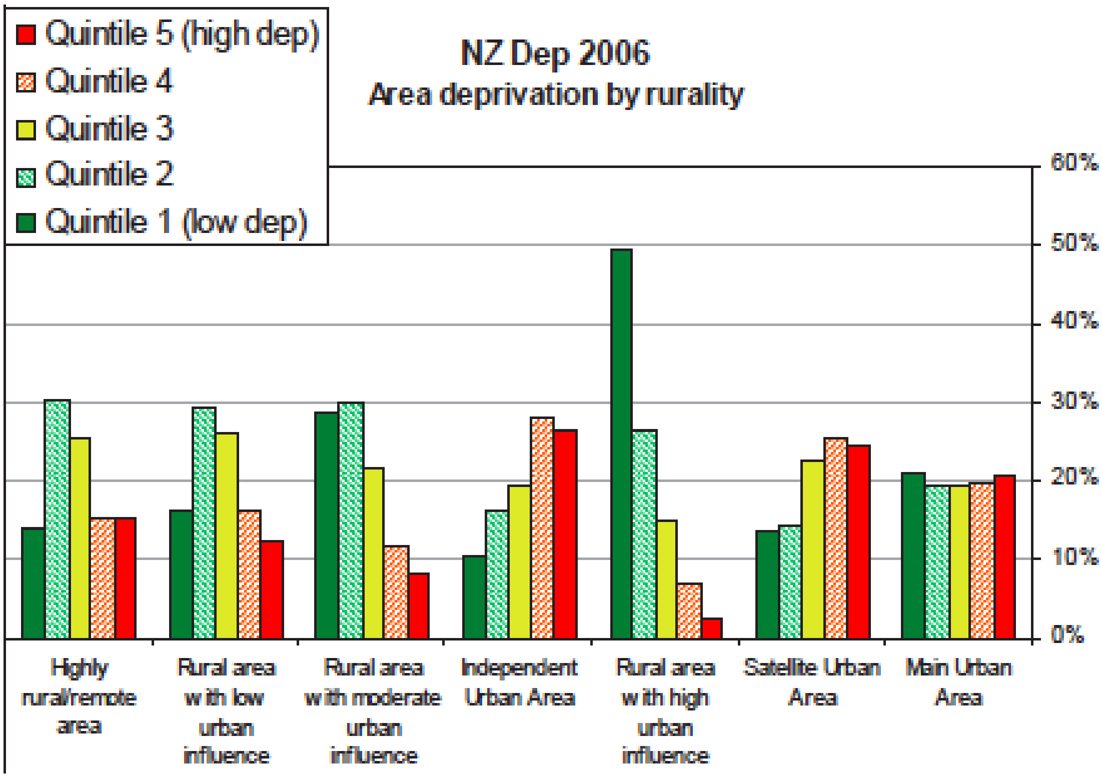
Only a minority of 'independent urban areas' contain specialist or base hospital services. Residents of 'rural areas with high urban influence', by contrast, have ready access to the health services in nearby 'main urban areas'.

Statistics NZ is undertaking a further revision of its rural-urban profile. The proposed new profile, the *Urban Influence Classification*, is due for release at the end of 2019. (22)

Socioeconomic status across the rural-urban profile

Figure 1 illustrates the socioeconomic status across the *Current Statistics NZ* rural-urban profile. The lowest levels of deprivation are found in 'rural areas with high urban influence' where the proportion of residents in quintile five (most deprived) is only 3%. 'Independent urban areas' have the highest levels of socioeconomic deprivation (27% in quintile five).

Figure 1: Area Deprivation by rurality (2006 New Zealand Index of Deprivation)



Source: 'Rural Health, challenges of distance, opportunities for innovation' report (17)

Because of the high levels of deprivation in these communities, it is worth considering the demographic features of 'independent urban areas' from a social and health perspective.

There are 89 'independent urban areas' in NZ. The smallest is Hanmer Springs (pop. 840), and the largest is Timaru (pop. approx. 27,000). Only four 'independent urban' communities contain base hospitals (Whakatāne, Timaru, Masterton and Blenheim). The remaining 85 are served by a combination of local rural primary care services, rural hospitals, and by travelling to distant base hospitals; that is 'rural health services'. (23) Rural hospitals, as defined by the Medical Council of NZ, are those hospitals staffed by rural general practitioners and rural hospitals generalists, with only very limited specialist services. (23)

Relative to residents in other categories in the *Current Statistics NZ* rural-urban profile, residents of ‘independent urban areas’ have: (17, 24, 25)

- Highest dependency ratio (ratio of the population <14 years and >65 years / working age population)
- Least likely to own a motor vehicle
- Lowest labour force participation
- Lowest median personal incomes and household expenditure
- Highest proportion of people on community wage – job seeker or invalid benefits
- Lowest rates of access to the internet and other telecommunications
- Highest likelihood of having a disability.

It is possible that economic factors may encourage low-income earners to migrate to ‘independent urban areas’. Lower housing costs in these areas mean that, despite having the lowest total household expenditure, residents of independent urban communities still spend a smaller proportion of their income on housing than do residents of other areas. (24)

‘Independent urban’ communities are also on average the oldest in NZ. In 2001, the median age of these communities was approximately three years higher than for NZ as a whole. (24) The older age structure, with higher proportions in the 60 to 70, 70 to 80 and > 80 age bands, is the reason these communities have the lowest working age population (60.3% vs. 65.3% overall) and the highest dependency ratios. The older age structure of NZ’s rural communities (relative to urban ones) is projected to increase over time. (26) This has obvious implications for the future health needs of these communities.

Ethnicity across the urban-rural profile

Thirty percent of Māori live outside of cities compared to 24% of non-Māori. (25) ‘Independent urban areas’ have the highest proportion of Māori of any of the geographic categories (20% of the residents of ‘independent urban’ communities are Māori, and 40% for independent urban communities in Northland, Bay of Plenty and Hawkes Bay). (24) This compares to the overall proportion of Māori being 14% of the NZ population.

Māori do not follow the same pattern of socioeconomic status across the rural-urban profile as do non-Māori (i.e. overall, the highest levels of deprivation are in ‘independent urban areas’ with higher socioeconomic status in true urban and more rural and remote areas). The relationship between socioeconomic status and rurality is more linear for Māori, with increasing deprivation seen with increasing rurality. This is closer to the relationship between rurality and deprivation seen in Australia and Canada. The lowest median personal incomes for Māori are for those living in ‘highly rural/remote areas’ ($16,400), followed by Māori in ‘rural areas with low urban influence’ ($18,000). (The national median personal income is $24,400). Māori comprise 25% of the population in quintile five in main urban areas. However, in rural areas (‘highly rural/remote’, ‘rural with low’ and ‘moderate urban influence’) over half the population in quintile five are Māori. (25) These figures would support the impression of rural health practitioners that, despite the relatively high overall socioeconomic status of the more remote parts of NZ, there exists significant pockets with very high health needs within these areas, represented by communities with a high proportion of Māori and high levels of socioeconomic deprivation (personal communications).

Rural Māori form an important at-risk population. The health disadvantage associated with Māori ethnicity, regardless of domicile, has been documented for a raft of health outcomes and access to health services. (2) Māori health is rightfully a national health and health research priority. Rural Māori may be more susceptible than rural Pākehā to the added impact of rurality on health outcomes and the part that access to services plays. This is due to higher health needs, less capital to invest in travelling to health services, and less choice when it comes to accessing culturally appropriate services. It is essential that rural health services are aligned to the needs of local Māori and can meet those needs in ways that are accessible and culturally appropriate.

To summarise, in contrast to the linear relationship observed between health status and rurality in Canada and Australia, the expected relationship in NZ might look more like a bell curve. This is because important social determinants of health in NZ's urban and very rural areas are similar, but higher levels of both socioeconomic deprivation and Māori ethnicity are found in rural towns. Half of all rural residents live in rural towns and the health status of these communities will have a significant effect on the measured health of rural NZers as a whole. It is also important to note that the pattern that might be expected for Māori may be closer to the linear one seen in Canada and Australia; that is, increasing socioeconomic deprivation and poorer health outcomes with increasing rurality.

Rural-urban health disparities in NZ

The urban vs. rural health disparities that would be expected, based on international experience and the ethnic and socioeconomic profile of NZ rural towns described above, have not been unequivocally demonstrated in NZ's health statistics.

The two major reports that have been published on the health of rural NZers have already been discussed with respect to the urban-rural profile they employed: the MoH 2007 report,(20) and the NHC 2010 report.(17) The following section considers the content and findings of these reports.

The MoH 2007 report used self-reported data in the national health survey and failed to identify significant and consistent rural vs. urban differences. Some of the key results are included in Table 4.

Table 4: Example of urban vs. rural health outcomes and access comparisons in MoH 2007 report.

Prevalence of:	
Heart disease	Urban higher
Diabetes	No difference
Arthritis	Urban higher
Osteoporosis	Urban higher
GP visit for injury or poisoning for men	Rural higher
Dental visit in last year	Rural higher
Hospital utilisation	No difference
GP visit for women in last year	Urban higher

Source: MoH 2007 report. (20)

The second report, "Rural Health: Challenges of Distance Opportunities for Innovation" (NHC 2010 report), came to the same overall conclusion that, '*life expectancy and other measures of health status are similar for rural and urban populations overall',* page X. (17) The NHC 2010 report did however note the role of rurality in accentuating the impact of socioeconomic deprivation and ethnicity on health outcomes, including mortality. In particular, it noted that rural Māori have a shorter life expectancy than urban Māori; 1.2 years for women and 1.5 years for men.

However, a closer reading of these two reports in combination reveals a deeper level of uncertainty about the quality of rural health data in NZ. This is illustrated in the conflicting conclusions drawn on the relative prevalence of ischaemic heart disease, despite basing these conclusions on the same dataset, the 2004 NZ Health Survey. The MoH 2007 report (page 9) concludes that, *"urban dwellers were significantly more likely to have been diagnosed with heart disease than rural dwellers"*, whereas the HRC 2010 report (page 68) concludes the opposite, that *"notable factors are that rural people are more likely to have ischaemic heart disease…"*

The prevalence of heart disease and stroke quoted in the MoH 2007 report and the NHC 2010 report relative to an urban incidence of 1.0 is found in Table 4 below. The discrepancy is more than 100%, with the 2007 MoH report suggesting that heart disease and stroke are much less common in rural relative to urban areas, with the NHC 2010 report suggesting, in fact, that the prevalence of these common and important diseases are much more common in rural areas.

Table 5: Relative reported prevalence of rural heart disease and stroke of rural NZ population (urban incidence=1.0)

Study		**Heart disease**	**Stroke**
MoH 2007		0.62	0.88
HRC 2010		1.66	1.71

Source: 'Poorly defined': unknown unknowns in New Zealand Rural Health. (27)

The variation is the result of different rural-urban classifications. The MoH 2007 report uses the *Old Statistics NZ Profile*, and the NHC 2010 report uses the *NHC profile*. (The majority of other health literature published in NZ in the last 15 years has used the *Current Statistics NZ profile*).

In 2016, we published a paper that explored the implications of the inconsistent and inappropriate approach taken to rural-urban classification in NZ health policy and research: ''Poorly defined': unknown unknowns in New Zealand Rural Health'. (27) This paper brought to attention the inconsistencies between the MoH 2007 and the NHC 2010 reports outlined above.

Successful classification systems group together things that are 'similar' with respect to the issue being considered. To be useful in generating data that meaningfully informs rural health service policy, the classification used needs to group into the same category communities that are similar with respect to health and health service needs. The *Old Statistics NZ Profile* was unhelpful in this regard. The majority of people who rely on rural health services live in communities of more than 1000 people, and are inappropriately classified as urban by the *Old Statistics NZ Profile*. The *Current Statistics NZ* Profile may be less helpful, classifying even smaller communities as urban e.g. Hanmer Springs (population 840). These smaller communities are included with slightly larger centres like Wānaka, Tākaka, Twizel, Murupara, Wairoa, Ōhakune and Dargaville in the 'independent urban area' category. All of these communities are clearly rural in NZ health terms.

The *Current Statistics NZ Profile* is problematic in a second respect because it misclassifies communities adjacent to large urban centres as rural (i.e. the 'rural with high urban influence' category = 22% of the total rural population). These are small (relatively affluent) census area units adjacent to large urban centres in which 'a significant proportion' of residents work and access services, including health services, in the adjacent urban area. Classifying these communities as 'rural' has the potential to further confound attempts to study the health effects of genuine rurality.

We estimate that the *Current Statistics NZ Profile* categorises 340,000 people who actually receive rural health as urban, while up to 124,000 of those in the rural category may actually receive urban healthcare. (27)

The NHC 2010 report recognised the inherent problems when trying to study rural health using the *Current Statistics NZ* profile, and proposed the alternative *NHC profile* (Table 3). The NHC used its profile to re-analyse some of the MoH Rural/Urban comparison data and in doing so came up with the radically different incidence of heart disease and stroke in rural and urban areas illustrated in Table 5 above. We are unclear as to why having uncovered these discrepancies the NHC did not comment on them. They appear to have put more weight on their analysis of life expectancy data, which by using their *HRC profile*, also failed to demonstrate significant overall urban-rural differences.

A third major MoH report looked specifically at the health of rural Māori and was published in 2012: *Mātātuhi Tuawhenua: Health of Rural Māori 2012*. (25) This report used yet another rural-urban classification, a further modification of the *Current Statistics NZ Profile.*

Table 6: Mātātuhi Tuawhenua Report rural-urban profile

Mātātuhi Tuawhenua Report Categories	**Corresponding *Current Statistics NZ* profile areas**
Main and satellite urban	Main urban areas
	Satellite urban areas
Independent Urban	Independent urban areas
Rural	Rural areas with high urban influence
	Rural areas with moderate urban influence
	Rural areas with low urban influence
	Highly rural / remote areas

Source: Mātātuhi Tuawhenua: Health of Rural Māori 2012. (25)

The Mātātuhi Tuawhenua Report Profile has both strengths and weaknesses. A major strength is that ‘independent urban areas’ are given their own category, meaning that the health outcomes for these vulnerable communities are analysed separately. Although not the focus of the report, this provides useful insights into health outcomes for residents of ‘independent urban areas’, both Māori and non-Māori.

Unfortunately, the Mātātuhi Tuawhenua Report Profile includes ‘rural with high urban influence areas’ in the ‘rural’ grouping. Including these communities, which are affluent and utilise urban health services, makes the outcomes for the rural grouping appear better than they would be if only genuinely rural communities were included. The effect that this misclassification has in ‘diluting’ rural-urban disparities is less pronounced for Māori because the proportion of residents living in ‘rural areas with high urban influence’ who identify as Māori is only 10%, the lowest proportion of all other geographic categories. The effect this has in ‘diluting’ rural-urban disparities for non-Māori is correspondingly greater.

Bearing in mind the limitations outlined above, the analyses in the Mātātuhi Tuawhenua report collectively paint a picture of poorer health outcomes for residents of ‘independent urban areas’ compared to those living in the cities and the more rural areas, an effect that is accentuated for Māori. These outcomes include reduced life expectancy and higher rates of avoidable and amenable mortality (Table 6). It is important to acknowledge that the urban-rural disparities are relatively small compared to those between Māori and non-Māori. The rates of amenable and avoidable mortality for Māori are 2.5 times those of non-Māori. Although smaller, the disparity faced by residents of ‘independent urban areas’ relative to main urban and more rural dwellers, is still significant (in the order of 20 to 30%), and probably unappreciated by health policymakers.

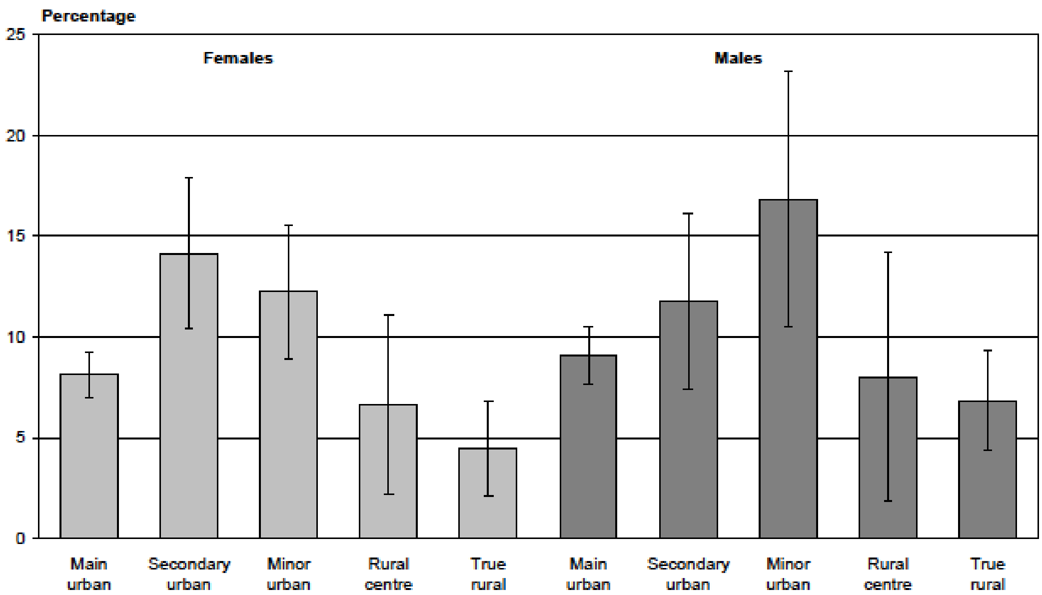
Table 7: Avoidable and amenable mortality, Māori and non-Māori aged 0-75 years, by urban-rural status, 2004-5.

Rate per 100,000	Māori			Non-Māori		
	Main and satellite urban	**Independent urban**	**Rural**	**Main and satellite urban**	**Independent urban**	**Rural**
Avoidable Mortality	251.5 (244.9-258.3)	295.3 (281.2-310.2)	255.4 (242.6-268.9)	99.3 (97.9-100.8)	125.7 (120.9-130.8)	96.7 (93.0-100.6)
Amenable Mortality	177.8 (172.3-183.5)	220.8 (208.6-233.8)	186.9 (175.9-198.5)	66.6 (65.4-67.8)	86.5 (82.5-90.8)	69.4 (66.2-72.7)

Source: MoH Mortality Collection. Rates are age-sex standardised to the 2001 total Māori population. (25)

The same pattern of poorer health outcomes in the small urban communities (i.e. rural towns) and better outcomes in both the cities and remote rural areas is apparent when other reports are examined more closely. An example is the prevalence of heart disease in the 2007 MoH report using the *Old Statistics NZ Profile* in Figure 2. This bell-shaped curve is the one based on how socioeconomic status and ethnicity vary across the urban-rural continuum. As discussed previously, this pattern contrasts with the more linear relationship between rurality and worsening health outcomes that have been identified in Canada and Australia.

Figure 2: Prevalence of heart disease, by sex and age type (age-standardised).



Source: Page 11 Urban–Rural Health Comparisons: Key results of the 2002/03 New Zealand Health Survey. 2007. (20) The categories used in Figure 2 are those in the *Old Statistics NZ profile*. The majority of residents of secondary urban and all residents of minor urban areas rely on rural health services. NB: Many of the residents of secondary urban centres (e.g. Oamaru) and all the residents of minor urban centres (e.g. Alexandra, Wairoa) are 'rural' on the basis of the health services they access.

Other studies

The Waikato-based National Institute for Rural Health undertook a Rural Health Indicators project that was reported in 2011. (28) The project appears to have been only partially completed, but data published online for five District Health Boards (DHBs) provides further evidence that the residents of 'independent rural areas' had, overall, poorer health outcomes than the residents of main urban and more rural areas.

A small number of studies looking at rural vs. urban outcomes for specific disease entities has been published. For example, rural Māori living in the Wairoa district have a higher burden of cardiovascular risk factors than urban Māori. (29) In a study using the *HRC Profile,* breast cancer survival for rural Māori women is significantly reduced compared to urban Māori. (30)

Alternative Rural Urban Profiles

In our 2015 NZ Medical Journal publication (27), we concluded that it is difficult to have a high degree of confidence in any of the reports and studies comparing the health of rural NZers because of the inconsistent array of urban-rural profile modifications used, at times producing radically different results from the same dataset.

We went on to propose a further modification of the *Current Statistics NZ profile* rural-urban profile (taking it a step further than the modification suggested by the National Health Committee), Table 8. The aim was to create a profile that best identified the population that accesses rural health services.

Table 8: Alternative urban-rural classification for health

	Statistics NZ (current)	Approximation of actual population accessing rural healthcare
URBAN	Major Urban 2,892,810 (72%)	Major Urban 2,892,810 (72%)
	Satellite Urban 128,094 (3.2%)	Satellite Urban 128,094 (3.2%)
	Independent Urban 440,000 (10.9%)	Independent Urban with DHB ‘base’ hospital ≅ 100,000 (2.4%)
		Rural with high urban influence 124,251 (3.1%)
	sub-total 86%	sub-total 81%
RURAL	Rural with high urban influence* 124,251 (3.1%)	Independent Urban without ‘base hospital’ ¶ ≅ 340,000 (8.5%)
	Rural with moderate urban influence 154,968 (3.8%)	Rural with moderate urban influence 154,968 (3.8%)
	Rural with low urban influence 220,470 (5.5%)	Rural with low urban influence 220,470 (5.5%)
	Highly Rural /Remote 64,182 (1.6%)	Highly Rural /Remote 64,182 (1.6%)
	sub-total 14%	subtotal 19%
	*Up to 22% (124,251/563,871) of people currently described as rural probably usually receive urban health services	¶Over 43% (340,000/779,620) people who actually use rural health services are classified as urban under the current definition

Figures represent 2006 population numbers (percentage as defined by Statistics NZ and the population actually accessing rural healthcare).

This classification has not, so far, been used to repeat any of the analyses in the MoH 2007 and NHC 2010 reports.

We have identified numerous other urban-rural classifications used in NZ research publications and policy reports. Some researchers have chosen to use health service boundaries (i.e. the catchment boundaries of rural general practices and rural hospitals). This includes several of the studies in this thesis (chapters 2 and 7). (31, 32) This classification makes sense when the aim of the study is to evaluate the effectiveness of a rural hospital or

GP-based service in improving service access and health outcomes for the catchment population they serve. It is, however, less useful when analysing nationally collected databases because these boundaries, in the absence of an agreed national approach, are locally and inconsistently determined.

Other classifications we have identified include: classifying any community of <100,000 as rural (University of Auckland for medical student intentions) (33); territorial land authorities population density (Medical Council of NZ for medical workforce distribution) (34); MoH GP rural ranking score (for the utilisation of primary care services) (35); drive time to the nearest base hospital, (for GP stress and job satisfaction) (36); drive time to nearest cancer centre (for cancer survival) (37); electoral boundaries (for asthma symptoms) (38); and self-reporting (RNZCGP GP workforce survey). (39)

In summary – Rural classifications and rural vs. urban health disparities

More than 17 different rural-urban classifications have been used to generate a confused and inconsistent picture of the health of rural NZers.

On re-examining the evidence, it is likely that, despite the conclusions of at least two major MoH reports to the contrary, rural residents face a health disadvantage relative to those in major cities, and that this can, in part, be explained by the low socioeconomic status and proportion of Māori living in rural towns. But this disparity has not been recognised because the most commonly used rural-urban classifications in NZ classify even small rural towns as urban. It is likely that the greatest burden is being borne by rural Māori who face the health disadvantages associated with socioeconomic deprivation, Māori ethnicity and rurality, the impacts of which are likely to be more than additive.

The social determinants of health will be having a greater effect on the health of rural people than will the healthcare they receive, as they do for other populations. However, because the papers in this thesis evaluate a series of health service interventions, it is worthwhile considering the ‘amenable’ health disadvantage faced by rural people; that is, the disadvantage that can be overcome by health system interventions. These include the rural healthcare workforce and access to quality healthcare services.

Rural healthcare workforce

Poor health outcomes in rural areas are frequently blamed, at least in part, on shortages of appropriately-skilled healthcare workers. It is, however, difficult to attribute with any certainty changes in health outcomes for a population to health workforce interventions, such as improved training or overcoming shortages. Exceptions to this include work undertaken by Barbara Starfield and Jack Wennberg and others, who have been able to demonstrate improved population health outcomes as a consequence of a greater emphasis on primary care and a generalist medical workforce. (40-42) There has not been any similar work undertaken that specifically looks at the rural healthcare workforce. Despite this, the link between health outcomes and the healthcare workforce is often made in rural health research publications and rural health policy statements. For example, the Delhi Declaration lists five points under the heading “Health for All Rural People.” The first acknowledges the importance of the socioeconomic determinants of health but the next three are all about workforce, namely teamwork, skill sets and scopes of practice. (8)

Rural health professionals themselves often understand rural vs. urban health inequities in terms of workforce shortages. This is not surprising given the impact these shortages have on individual rural health professionals, both professionally and personally. This includes NZ, where the majority of rural health publications have concentrated on workforce issues. (43) In his 1999 publication, "Benign Neglect of Rural Health: is positive change on the way?", Ron Janes identifies 29 potential "solutions for improving rural health", 22 of which relate directly to workforce training, recruitment and retention. (44)

The geographic maldistribution of the health workforce is recognised as a global problem. The Delhi Declaration notes that while 50% of the world's population lives in rural areas, only 38% of the world's nurses and 24% of doctors do so. (8)

NZ is no exception and rural shortages exist for a range of health professional groups. (45-47) Longstanding shortages are, however, best documented for doctors where doctor shortages have been monitored for more than two decades. (48-51) The important findings by Goodyear-Smith and Janes in 2005 were that the NZ rural medical workforce was older (72 percent > 40 years) and likely to retire within two (14%) or five (20%) years. In the 2014 Royal NZ College of General Practitioners (RNZCGP) workforce survey, the rural medical workforce was, when compared to the urban workforce, more likely to have graduated from an overseas university, to be male, and to work longer hours. (52) In many respects it was similar to the workforce in 2005. The age structure remained the most concerning feature of the workforce. More rural respondents were aged ≥ 55 years than urban respondents (38.2% rural vs. 32.6% urban; p = 0.0396). Furthermore, 21.5% of rural respondents were aged ≥ 60 years compared to 16.5% of urban respondents (p = 0.0263). (The RNZCGP uses self-reporting to classify whether or not a doctor is rural or urban). In a 2011 publication, Garces-

Ozanne et al highlighted the apparent unwillingness of NZ graduates to work in rural areas and the reliance on international medical graduates to fill shortages. (53)

These findings are supported by the NZ Medical Council Medical Workforce Reports in 2013 and 2014. (34) Table 9 below is copied from page 21 of the report and summarises the important findings. Fewer doctors, including GPs, live in rural areas and those that do are older and spend more hours on call.

Table 9: Summary of workforce statistics by population area density.

	Population density		
Workforce measure	Main urban 100+ people per km^2	Secondary urban 21-99 people per km^2	Rural 0-20 people per km^2
Total doctors	9,575	1,721	1,543
Total GPs	2,474	623	807
Population	2,603,162	799,932	1,106,520
Doctors per 100,000 pop	367.8	215.1	139.4
GPs per 100,000 pop	95.0	79.0	72.9
Average hours worked	44.0	42.8	42.2
Average hours worked by GPs	33.9	34.7	37.4
Average on call hours	4.6	5.7	7.4
Average age	45.5	46.9	49.5
Proportion of female doctors (%)	43.5	41.1	36.9
Proportion of IMGs (%)	39.1	45.1	55.9

Source: Medical Council of New Zealand. The New Zealand Medical Workforce in 2013 & 2014. Wellington: Medical Council of New Zealand; 2016. Pg 21 (34) The MCNZ used the population density of the territorial land authority (district council) to determine rurality.

Because the diagnostic services evaluated in this thesis are based in small rural hospitals, it is worth paying particular attention to the rural hospital medical workforce.

Rural hospital medical workforce

A series of seven articles on the NZ rural hospital medical workforce were co-authored by the candidate and are included in the appendix as background to the thesis. These publications are summarised below, and include two workforce surveys,(54, 23) three publications describing the new rural scope of practice, (55-57) and two publications describing academic and vocational training programmes. (58, 59)

NZ's rural hospitals are staffed by rural generalists who undertake hospital work full time, or combine it with rural general practice. In the past, shortages in the hospital workforce may have been even worse than in the primary care rural medical workforce. The first rural hospital workforce survey was undertaken in 2009 (Lawrenson, Nixon, Steed). Only two of the 26 hospitals that responded reported an adequate supply of qualified medical staff, with 75% of hospitals reporting a 'serious or critical shortage'. (54) These more subjective findings were supported by quantitative data suggesting a third of permanent rural hospital medical posts were vacant. More than half of the respondents had worked additional shifts in the last month to cover shortages in the hospital.

Workforce shortages are only part of the picture. The Delhi Declaration notes the fundamental importance of an appropriately trained and well-organised workforce. (8) Competent rural practice demands a distinct set of technical skills supported by a defined body of knowledge. (60) In addition, a set of 'soft skills' is needed to overcome professional isolation, retain and use skills that may only rarely be needed and, in particular, deal with the increased uncertainty of working in an environment with limited diagnostic tests and immediate specialist advice. These attitudes have been collectively called ‘clinical courage’. (61)

It is not surprising that when a Rural Hospital Doctors Working Party was formed in 2005, they prioritised the development of recognised standards for training and ongoing professional development as the initiatives most likely to overcome the workforce shortages in the medium to long term. (55) The 2009 workforce survey confirmed that the professional and educational structures needed to set and maintain these standards were lacking: 42/69 (61%) of rural hospital doctors said there was no formal medical leadership in their hospital; only 34/69 (49%) said there was a process of clinical governance; and 36/69 (52%) said there was a credentialing process for medical staff. (54)

As a result of the work undertaken by the Working Party, a series of important initiatives were introduced in 2008 changing the professional status and training for rural hospital doctors. (55-59) The Medical Council of New Zealand recognised rural hospital medicine as a new scope of practice, the RNZCGP created a Division of Rural Hospital Medicine, and the Clinical Training Agency (now Health Workforce New Zealand) allocated funding for a Rural Hospital Medicine Training Programme. These institutional structures and programmes were different to the arrangements that support other, more established scopes of practice. Examples of these differences include the level of integration with existing institutions, in particular the RNZCGP and the Universities. (59) High levels of flexibility and recognition of prior learning were built into the training programme, making it possible to train concurrently in rural hospital medicine and another vocational scope. This flexibility included integration with existing general practice training and linking vocational training with an existing postgraduate university qualification.

Early indications are that these initiatives have had a positive impact on the rural hospital workforce both with respect to numbers and professional standards. (23) When repeated in 2015, the survey revealed that the percentage of vacant positions or positions filled by locums, had fallen from 32% (in 2005) to 5.7% (in 2015). Most doctors working in a rural hospital were now vocationally registered or in training. Thirty percent of hospital managers indicated that there was now an adequate supply of doctors in their hospital, although a quarter indicated there was still a serious or critical shortage. In 2015, 80% of rural hospital doctors said there was now active clinical governance in their hospitals. The majority of rural hospital medicine trainees are concurrently undertaking general practice training (‘Dual Fellowship’ pathway). This pathway prepares doctors to work across the entire scope of ‘rural generalist medicine’ as defined in the Cairns Consensus and is therefore adding to the rural primary and secondary care medical workforces. (59, 60)

Targeted rural postgraduate training programmes are one of the three evidence-based strategies for increasing the uptake of rural careers. The others are interventions at undergraduate level. (15)

Undergraduate rural programmes

A number of published studies of rural health initiatives in NZ's undergraduate medical programmes are aimed at increasing the uptake of rural careers. (62-64) There are indications that these programmes are encouraging students to return to provincial areas for their postgraduate house officer years. However, the longer-term results for the medical workforce in smaller rural communities remain disappointing. Only 1.6% of NZ medical students express an intention to work in communities with populations of less than 10,000 at the time of graduating, down from the 5.4% who express an intention to work in these communities at the point of entry to medical school. (65)

In summary, although the link between workforce shortages and poorer health outcomes has not been unequivocally made in rural health, this link is frequently assumed in both international and NZ publications. NZ faces the same geographic maldistribution of its medical workforce, with chronic shortages in rural areas. Recent evidence about the intended career locations of new medical graduates suggests that this maldistribution is likely to continue into the medium term. Some progress has been made in creating a career pathway for rural generalist doctors and this may be starting to have an impact on workforce shortages for this group.

Rural secondary care health services

The body of research published on rural healthcare services, and their ability to influence health outcomes for rural NZers, is much smaller than that published on the rural workforce. Even fewer studies have focused on rural secondary care services. Three descriptive studies of NZ's rural hospitals describe the services they provide and the conditions they manage. (66-68) But as far as we are aware, there is only one study that evaluates the impact of an in-patient rural hospital service on the traditional health outcomes of mortality and morbidity. (69)

In 2011, we published the survival data for patients admitted to hospital with acute myocardial infarction (AMI) in Central Otago (196 patients from 1995 to 1999). (69) Central Otago (with a population of 21,000 in 2002) is serviced by Dunstan Hospital, the NZ rural hospital that is most distant from base hospital specialist services (220km) and manages, at least initially, all AMI presentations for Central Otago residents.

The in-hospital mortality rate for Central Otago AMI patients was 5.6%. The cardiovascular mortality rates were 7.7% at 30 days, and 13.6% at one year. The all-cause mortality rate at one year was 15.4%. These outcomes compared favourably with comparable figures published around the same time. The in-hospital mortality of 1,081 patients presenting with myocardial infarction in Auckland in 1995 was 12.8%. Mortality rates for a large number of Scottish patients were 18% at 30 days, and 27% at one year. (69)

The study was designed to evaluate the outcomes of a model of care that had been designed to ensure rural patients with AMI were, despite distance, able to access the expert opinion of urban-based specialist cardiologists and timely cardiac interventions. The model of care was unusual at the time and involved close collaborative working arrangements between Dunedin-based cardiologists and the local rural generalist doctors. Although 220 km away, the cardiologists continued to have considerable input into the patient's management, including determining when they would benefit from, and should be transferred for an interventional cardiology procedure. This was done with regular virtual telephone-based ward rounds and regular case reviews.

A similar study undertaken in 2000-2002 examined outcomes for a provincial hospital near Dunstan Hospital, with no interventional cardiology service and without the same service model of joint care with the distant base hospital cardiologists. The study concluded that outcomes were significantly inferior to those being achieved by the referral cardiology centre. (70) Patients admitted to the provincial hospital were less likely than tertiary hospital patients to receive an angiogram or evidence-based medical therapies, and had twice the one-year mortality (22.1% vs. 10.7%). This study included unstable angina as well as AMI patients, and outcomes would therefore be expected to be better than those in the Dunstan cohort.

When considered together, these studies suggest that while many patients with myocardial infarction living in Southern NZ at a distance from tertiary hospital services had poorer outcomes, a well-designed and collaborative model of rural healthcare could overcome this disadvantage and achieve comparable outcomes for rural patients. This was an important consideration when designing the rural diagnostic services that are evaluated in this thesis.

Equity of access to secondary healthcare services for rural NZers

Although morbidity and mortality are the traditional health outcomes, equity is also recognised as a desirable outcome when evaluating rural health services. (71) Indeed, it is the experience of this candidate that equitable access to services is the outcome best understood by rural communities and healthcare workers, who are acutely aware of the differential access in health services between rural and urban areas (personal communication with Dr David Fearnley).

In NZ, geographic variation in health service delivery is routinely reported by comparing District Health Boards (DHBs), or comparing larger regions based on the old Health Funding Authorities e.g. Midlands region. Examples include the MoH National Health Survey (72) and ANZACS QI (registry for acute coronary syndromes) database. (73) On occasion (e.g. National Health Survey) (72) territorial authority areas (regional councils) are also used. None of these comparisons is helpful in delineating rural disparities as all DHB and regional council areas encompass both urban and rural communities.

Specific rural vs. urban comparisons of access to health services are not routinely reported in NZ, either nationally or within DHB regions; and only a tiny proportion of what has been reported relates to access to the diagnostic and treatment services normally delivered from a hospital i.e. secondary care service.

Some limited findings can be found in the NHC 2010 report. These include some age-adjusted utilisation rates that are higher for rural than urban people: outpatient services (11% higher); emergency department visits (20% higher); public hospital use (excluding ED) (20% higher); and Accident Compensation Corporation claims (6% higher). There was only a small difference in GP consultations (-1%). Little detail is provided as to how these results were derived. They do not appear to have been adjusted for ethnicity or socioeconomic status, and there is no breakdown by region and service, which would have permitted a greater understanding of these differences. As already discussed, the differences observed may have been impacted by the rural-urban profile used in this analysis. These results also contrast with the results of the study included in this thesis on access to CT services. (31) It is not possible to discount the NHC 2010 report findings completely, but there is enough doubt to suggest that these analyses should be repeated using a fit-for-purpose urban-rural classification. (27)

Barriers to accessing secondary healthcare services for rural NZers

When considering access to health services for rural patients, it is important to consider all the potential barriers to access, not just distance. The Delhi Declaration includes geographic, social, economic, political, ethnic and cultural barriers. (8) The NHC developed a similar list: socioeconomic deprivation; transport; telecommunications; the cost of accessing services; and service acceptability. (17) The socioeconomic profile of rural towns (with a high proportion of Māori, low incomes, limited transport and telecommunications) not only increases the need for health services, it also accentuates the barriers to accessing them.

In 2016 we published a survey of patients attending specialist outpatient clinics at Dunstan Hospital, *"The price of 'free'. Quantifying the costs incurred by rural residents attending publicly funded outpatient clinics in rural and base hospitals"*. (74) The study examined 'cost' as a barrier to accessing secondary services for rural patients, and was modelled on a survey undertaken in rural Australia in 2001. (75)

The costs incurred by patients to attend a specialist outpatient appointment were quantified, including travel and accommodation, and time taken off work for both the patient and, if necessary, a companion to accompany them. The Central Otago population is dispersed and there are costs associated with attending an outpatient appointment whether that be to see a visiting specialist at the local rural hospital or at the more distant base hospital. The median distance travelled to attend the rural clinic was 93 km with 32% of respondents travelling more than 150 km return. The base hospital is an additional 440 km return journey for almost all the respondents. We compared these costs to calculate the savings to the patient when the service was provided at the local rural hospital.

The average savings associated with the rural service (Dunstan) compared to the distance base hospital (Dunedin) were substantial, as seen in Table 10.

Table 10: Average cost to attend specialist outpatient clinic at rural and base hospital

	Rural hospital	Base hospital	Difference
Travel time	96	389	302
Paid time	52	115	63
Accommodation	-	60	60
Sub total	148	537	425
Unpaid time	34	159	125
Total	182	732	550

Source: The price of 'free'. Quantifying the costs incurred by rural residents attending publicly funded outpatient clinics in rural and base hospitals. (74) All values are in NZ$.

Rural people must make a significant financial investment to access ‘free’ healthcare, especially when multiple appointments and/or visits to base hospital clinics are involved. Over half (61%) of all respondents reported that the cost of local outpatient attendances at Dunstan Hospital ‘significantly affected’ their weekly budget (in 24% of cases the effect was rated as moderate or large), but only 8% reported being entitled to financial assistance to attend these clinics. As we have demonstrated, the financial burden would have been much greater if they had to travel to Dunedin for the service and the percentage of patients facing financial hardship as a consequence is likely to be much greater. It is also possible that health professionals’ awareness of the costs may subliminally effect the decision making associated with referrals for rural people.

In the 2016 Commonwealth Fund Health Policy Survey, NZ was ranked third highest among 11 similarly affluent countries in the percentage of adults who faced cost-related barriers to healthcare in the past year (17 percent). (76) Our survey would suggest that this percentage could be considerably higher for rural NZers who have to travel large distances to access the healthcare they need. In rural areas with high levels of social deprivation, the barriers will be even greater.

Summary: Rural-urban health status disparities in NZ

Given the socioeconomic status and ethnic makeup of NZ's rural towns, the financial barriers to accessing healthcare services, and the geographic maldistribution of the medical workforce, it is surprising that NZ has not clearly demonstrated the rural vs. urban disparities in health status and healthcare access seen in similar countries. This could be because the relationship between socioeconomic status and ethnicity across the rural-urban continuum is not as linear as it is in similar countries. But it seems more likely that this is the result of inappropriate rural-urban classifications. When looked for carefully, there is evidence of poorer health outcomes for residents of rural towns in particular. At the very least, there is an argument for developing a fit-for-purpose urban-rural health classification and a closer examination of the health status of rural NZers.

NZ rural health literature

A literature review was undertaken as part of each of the studies in the thesis and the relevant international and local literature is cited in the relevant publication.

The results of these searches align with the comprehensive review of NZ’s rural health research undertaken in 2006 by John Fraser, School of Government, Victoria University, on behalf of the National Health Committee. (77) The majority of the studies identified in Fraser’s search related to the healthcare workforce, and the rural general practice workforce in particular. Only a small number of publications dealt with the health needs of rural populations and almost none with rural vs. urban differences in health outcomes and access to services. In the review, Fraser expressed the hope that the impending (2007) publication of MoH Urban Rural Health Comparisons would fill this gap. The limitations of the MoH report are discussed earlier in the introduction. Fraser identified several publications that deal with models of rural primary care delivery. Two publications describe the services provided by rural hospitals in NZ. The review failed to find any previously published studies set in rural NZ that reported on the use of point-of-care ultrasound, point-of-care laboratory testing, computed tomography or cardiac exercise testing.

John Fraser was surprised at the paucity of publications on rural health in NZ given the importance of rural communities to NZ as a whole and the quality of nationally-collected health data in NZ, data that should have facilitated his research. He highlights this in the report’s concluding paragraphs:

> From a policy perspective, the defining difference between New Zealand and other countries with large rural regions and a largely publicly-funded health and disability sector is that New Zealand has not examined its local context nearly as thoroughly as other jurisdictions. This creates serious challenges for a locally relevant literature review of this kind.

> The fact that 14% of the New Zealand population live in rural areas, the importance of rural areas to our economy and society, and the mark that New Zealand's strongly rural history still leaves on the New Zealand psyche, together mean that the health and independence of rural people should properly be the concern of policymakers and wider New Zealand society. According greater attention to rural health, starting with the development of informative data sources, is the least we can do.
>
> Source: Fraser J. Rural Health: A Literature Review for the National Health Committee. Page 61. (77)

The focus of this thesis is diagnostic health services

Few firm conclusions can be drawn about rural-urban disparities in access to diagnostic services in NZ. But it is possible that rural communities are particularly vulnerable to inequitable access to diagnostic services, and that overcoming this inequity will have a greater impact on health outcomes than access to other secondary healthcare services. Modern technology, particularly laboratory testing and medical imaging, are essential components of the diagnostic process. However, because many of these tests are complex and expensive, and therefore hospital- and specialist-based, ensuring equitable access, regardless of place of residence, poses considerable challenges. And because diagnostic tests are often a necessary first step in the diagnostic process that determines who will receive what treatment, system-wide inequity is inevitable unless there is equity of access at this initial stage.

The papers that form the body of this thesis provide additional insights into the access rural NZers have to diagnostic services. The primary aim of the thesis, however, is to evaluate the ability of a series of rurally-based diagnostic services to improve access for rural populations.

Where health services are located has cost implications for both patients and the health service. Health economic evaluations are therefore important, and it is worth summarising the basic principles as they relate to rural health services.

Health economics

The resources available in NZ's public health system are finite and the true cost of providing a new diagnostic service in a rural area (indeed of any publicly-funded health service) is 'what will not be provided elsewhere in the system that can generate the maximum benefits', i.e. the opportunity cost. (78) The rational allocation of public health resources therefore demands an understanding of the relative costs and benefits of competing health service priorities. This is achieved by undertaking economic evaluations, the different types of which will be discussed later in this section.

Cost is frequently used to justify the centralisation of healthcare services in urban areas. Because of lower usage and potentially higher running costs, expensive technologies are often less cost effective in rural areas. The marginal cost incurred by an established urban service increasing its volume is usually lower than the costs of establishing a separate, and often low volume, service in a rural area. At the same time, new technologies occasionally provide an opportunity to offer a service in a rural area that in the past would not have been cost effective.

There are several other health economic principles that need to be considered when evaluating a rural health service. The fair and equitable distribution of healthcare resources is of particular importance to rural communities and it is not surprising that Reeve et al have included equity as an outcome in their rural health service evaluation framework. (71) Although it can be, equity is often not considered by health economists. Indeed, equity of access often conflicts with cost effectiveness when considering the geographic distribution of health services. ‘Marginal analysis’ is therefore an important concept; that is, increased service provision does not result in greater health benefits in a linear fashion. The cost benefit of establishing a health service in an under-served high-needs rural area may be more favourable than an increase in the volume of that same service in an already well-served urban area. This is because the greater health benefits of the rural service outweigh the higher costs. (78) This principle is perhaps best understood by clinicians as the ‘pre-test probability’; the value of a diagnostic test depending on the prevalence of the disease in the population being tested.

The siloing of health service budgets is usually based on the dominant urban models of healthcare organisation (particularly the primary-secondary split). This also impacts on the viability of rural health services because the benefits often go to a different ‘payer’ in the health system and the service still appears unaffordable. (79) For example, a rural point-of-care laboratory service may result in reduced patient transfers and base hospital admissions, creating an overall cost saving to the healthcare system, but the costs may all fall on the rural health service (i.e. the laboratory costs and the cost of managing patients locally who would otherwise have been transferred).

When considering public health services that are free at point-of-care, it is common for economic evaluations to only consider the perspective of the funder. This can hide the real costs to rural communities. (78) Centralising health services often involves shifting costs to individual rural patients and whānau. Sometimes these costs are easily quantifiable, as applied in Fearnley et al, in which we quantified the costs of travel, accommodation and time off work faced by rural patients when attending specialist outpatient appointments. (74) Sometimes these costs, though equally important, are more difficult to quantify. An example are the ‘spiritual costs’ to patient and whānau of shifting an unwell elderly Māori patient from their ‘place’ and community to a distant urban hospital. It is, however, still possible to link these costs to ‘Quality added life years’ (QALY) in a cost-effectiveness analysis, or to explore these costs using qualitative methodology.

Types of economic evaluations: Cost minimisation analysis considers only the cost of the service. (79) An assumption is made that the benefits of the competing services are the same, which is frequently not the case. When considering urban- vs. rurally-located services this may be because of differences in the quality, safety or even nature of the services, or it may be due to differences in the health needs of the rural and urban populations. These analyses are simple to perform and of particular value when the urban and rural services have comparable benefits, or they are combined with evidence of service quality and population health need. (79) Costs are normally expressed in dollar terms. It is possible, however, to use other variables as an indicator of costs e.g. the number of patients transferred and admitted to a base hospital from a rural area, length of hospital stay or readmission rates. (79)

Higher level economic evaluations permit a more robust comparison of the value of different healthcare interventions. However, these evaluations are inherently more complex because they involve quantifying the benefits. In a traditional cost-effectiveness analysis, the benefits are quantified in natural units (such as cases detected, events prevented, lives saved etc.). These sorts of analyses become even more complicated when evaluating a diagnostic service, which is not a health benefit in itself but rather an intermediate outcome along the path to a potential health benefit. (78) As Reeve et al have done, it can be argued that when considering a rural health service, equity of access is a desirable health outcome in itself. (71) Utilisation, which can be readily quantified, can then be considered a benefit for the purposes of a cost-effectiveness analysis. This would simplify the process of conducting a cost-effectiveness analyses of rural diagnostic services considerably.

Cost utility analysis is a particular subgroup of cost-effective analysis that expresses the benefits in terms of the impact on quality and quantity of life, usually as 'quality adjusted life years' i.e. QALYS. This type of analysis demands the collection of detailed data on the health status of the participants. (79) Cost-utility analysis permits the comparison of interventions that have quite different outcomes, e.g. hip replacement and coronary artery bypass surgery.

In a true cost benefit analysis both the costs and the benefits of the health intervention are valued in monetary terms. This sort of analysis requires the collection of large amounts of data. It also raises the issue of how to quantify in monetary terms benefits such as lives saved or reduced pain and suffering. (78, 79)

None of the studies included in this thesis were resourced for complex economic evaluations and instead employed simple cost minimisation analyses. The limitations of this approach are discussed further in the conclusion.

Māori health

The demographics and consequent health needs of rural Māori are considered earlier in this introduction. Other important issues for rural Māori that need to be considered in this thesis include: the cultural responsiveness of rural health services *and* rural health research; and generalisability, i.e. how applicable research findings are across NZ's very diverse rural communities.

Rural health services have a particular advantage in providing culturally-responsive services for rural Māori because they are provided close to home, often by local community-owned healthcare providers. The importance of this is highlighted in the following paragraph, which is taken from chapter 8.

> The effect of (a locally provided health service) on reducing the need for transfer takes on additional meaning for this community from a cultural perspective. For local Māori other social and cultural priorities can take precedence over health matters. Local Kaumātua (elderly), especially, have an intrinsic connection with their whānau (family), whenua (land), their living environment, their sustenance, and are concerned with their 'kaitiaki' responsibilities, which are left bereft in their absence. While away from home they suffer emotionally as a result. Their spirit is diminished and healing takes longer. Thus, frequently the sicker they are the less likely they are to agree to

> transfer to a distant base hospital. It is not unusual for a patient to be so concerned about dying far from their traditional home that they will decline transfer despite compelling medical reasons. (80)

There are parallels with rural health research. When research is undertaken in predominantly Māori rural communities, such as the Hokianga, it needs to be conducted in a way that is consistent with the values and processes of that community, ‘the way that it is done here’. Marara Koroheke-Rogers from Hauora Hokianga, guided this process in the three thesis studies that were conducted in her community. While the implications of the study results as they pertain to rural Māori are discussed in each of the publications, the process of conducting the research in these communities is a parallel but hidden story. Marara describes this process in a separate article, *‘Kete pikau: A basket of knowledge - 'guidelines from back home', Aust J Rural Health 2018’*. (81) Marara emphasises the importance of te tomokanga, the process of building relationships according to local protocol. Only when this process is completed (the researchers are no longer strangers) and tautoko (approval) from ngā kaumātua, elders is granted, can the business of the research be considered.

There are large differences in the proportion of residents that report Māori ethnicity across NZ’s rural communities. Three of the four studies in this thesis, including the largest, were undertaken as part of a partnership between Central Otago Health Services and Hokianga Health Enterprises Trust, building on earlier work. (82) These community-owned health companies serve communities at either end of the country with very different ethnic and socioeconomic profiles. This was done intentionally, in the expectation that by including these very different communities there was a greater chance of generating results that could be generalised. The Hokianga population is predominantly Māori (74%) with a deprivation index of 10, whereas only 6% of permanent residents in Central Otago are Māori, and the deprivation indices in the mesh blocks that comprise Central Otago range from 2 to 7. (32, 83)

Evaluation framework and research questions

When the studies in this thesis were undertaken, there was no consideration given to the use of a formal rural health service evaluation framework. When bringing together the studies into this thesis, an effort has been made to identify a relevant framework.

There has been a paucity of rural health service evaluations undertaken internationally. (71) However, in 2014 Reeve, Humphreys and Wakerman published a comprehensive health service evaluation and monitoring framework designed specifically for use in remote primary care health services. (71) Based on key principles of primary healthcare evaluation, (40, 84) the framework also takes into account the distinctive features of rural communities and their health services, in particular the integration between primary and secondary care. I have used Reeve's framework to conceptualise the role of the indicators used to evaluate the rural diagnostics services in this thesis.

In their model, Reeve et al evaluate health service performance across the three domains developed by Avedis Donabedian: structure; process; and outcomes. (84) Structure and process performance are evaluated with respect to the accepted principles of primary healthcare evaluation: accessibility; appropriateness; effectiveness; responsiveness; and efficiency. These principles are then used to generate a set of indicators to evaluate the services. Equity is recognised as an outcome along with more traditional outcomes such as mortality and morbidity.

The performance indicators used in the series of studies in this thesis are presented within Reeve et al's framework in Table 11.

Table 11: Evaluation framework for rural diagnostic service

Domain	**Performance Measure**	**Indicator used in the studies that form this thesis**
Structure	Accessible	Locally available. Available when needed.
Process	Appropriate	The service is meeting a health need – demonstrating under-serving prior to establishing the service. Quality assured – meets recognised quality standards. Culturally appropriate.
	Effective	Improves diagnostic certainty. Demonstrates a positive impact on patient care.
	Efficient	Economic evaluation. No evidence of over-servicing (utilisation rates not significantly greater than urban rates).
Outcomes	Mortality	
	Morbidity	No evidence of patient harm.
	Well being	Reduced (unnecessary) inter-hospital transfers.
	Equity	Increased rural utilisation rates. Service quality measures similar to urban-based service.

An evaluation framework for the diagnostic services studied in this thesis. Based on Reeve et al. (71)

The indicators address a series of research questions that are applied to the rural diagnostic services being evaluated:

1. What is the extent of existing rural vs. urban disparities in access to this service?

2. Do rural vs. urban differences in access to diagnostic services translate into differences in health outcomes?
3. Does establishing a rural service address access inequities?
4. Is the service appropriate, with particular reference to appropriateness for rural Māori?
5. Does the service meet recognised quality standards? Is it safe?
6. Does the service aid diagnostic decision making?
7. Does the service have an impact on patient management?
8. Is the service cost effective?
9. Does the service improve patient outcomes?

Aims of the thesis

The aim of this thesis is to examine strategies to improve equity of access to diagnostic services for rural populations in NZ.

This is approached through a series of studies, each of which evaluates the accessibility, appropriateness, effectiveness, efficiency, and impact on health equity, of a rurally-based diagnostic service.

Chapters

Each chapter in the thesis is an article that is reproduced in full, as it was originally published in a peer reviewed journal. This is consistent with the MD regulations, which is a degree by publication, including work published prior to enrolment. It is important to note that each of the articles was intended as a stand-alone paper. Because several of the articles present different findings from the same study, there is inevitably some repetition in the introduction and methods sections.

The thesis encompasses four studies. Chapters two to five are a study into rural vs. urban disparities in access to CT services in southern NZ, and the effect the rural CT service in the rural town of Oamaru had in reducing these disparities. Chapters six and seven evaluate a new point-of-care laboratory service in the Hokianga. This study takes the evaluation of rural diagnostic services a step further by considering the effect on patient management. New cardiac exercise testing services, at Rawene and Dunstan Hospitals, are evaluated in chapter eight. This is the first study to consider a skill dependent service, raising important issues of quality and safety. The largest study in the thesis evaluates the impact of clinician performed point-of-care ultrasound in six NZ rural hospitals. The findings are presented in chapters eight to twelve. Point-of-care ultrasound is a highly technical, operator dependent service. The important issues of quality and safety are therefore considered in depth in this study, as is the effect on patient management. Chapters ten to twelve present sub-group analyses of individual scan types.

Chapter 2: Geographic disparities in the utilisation of computed tomography scanning services in southern New Zealand

Context statement

The first study in the thesis considers the first of the research questions: *'What is the extent of rural vs. urban disparities in access to diagnostic services in New Zealand?'*. Because it provides evidence of an unmet rural health need, the answer to this question is an important first step in justifying new rural health initiatives to improve access to services.

This study addresses question one by quantifying the geographic variation in the utilisation of CT in southern NZ. The results demonstrate that rates of CT utilisation in rural areas are much lower than those in nearby urban communities, providing evidence of significant inequity in access to an important diagnostic service, and evidence for the *appropriateness* of the rural CT service evaluated in chapter 4.

Apart from some limited data on access to cardiac exercise testing in chapter 7, this is the only study in the thesis that uses service utilisation data to quantify rural-urban inequalities in access to a service. As far as we are aware, this is the only study published in NZ comparing urban vs. rural utilisation of a common diagnostic service.

Differences in utilisation rates are not in themselves evidence of disparity in access to a service. Instead, they may be an appropriate reflection of differences in disease burden between the populations being studied, or a reflection of unnecessary over-servicing in the high access population.

In this publication we argue that the large urban-rural differences in utilisation demonstrated in this study were very unlikely to be the result of differences in disease burden.

If higher levels of utilisation of a service in urban areas are a reflection of over-servicing then the differences will not result in poorer health outcomes for the under-served rural population (as measured by higher *mortality* and increased *morbidity,* the traditional health outcome measures). It is then easy to dismiss lower levels of service utilisation in rural areas as urban over-servicing that is of no consequence to rural health outcomes. This is difficult to disprove, especially given the small numbers and therefore limited power of most rural studies. Perhaps for this reason, Reeve et al have included *equity* as an outcome performance measure when evaluating rural services; that delivering comparable levels of service for rural and urban communities is seen as a desirable outcome in itself, even when it has not been demonstrated that achieving comparable levels results in improved outcomes as measured by mortality or morbidity.

CT scanning was chosen as the diagnostic service to study because it is a common investigation used in most specialties and for a wide range of conditions. It is therefore likely that differences in access to CT are indicative of widespread urban vs. rural differences in access to secondary care services, including in the other services evaluated in this thesis for which we do not have data on rural-urban utilisation rates. At the very least, further research needs to be undertaken to determine whether or not similar rural vs. urban differences exist for other secondary care services and in other parts of NZ.

Nixon G, Samaranayaka A, de Graaf B, McKechnie R, Blattner K, Dovey S. Geographic disparities in the utilisation of computed tomography scanning services in southern New Zealand. Health Policy. 2014;118(2):222-8.

Introduction

In New Zealand the utilisation of complex health services is routinely compared across the large regions that are used to manage public health funding. (85, 86) Little analysis is undertaken of variation within these regions. In particular there is little information on the impact of distance on the utilisation of urban based secondary services. This is in contrast to primary care where inequalities are acknowledged and there is both research and policy aimed at improving access for rural communities. (20)

In this paper the utilisation of one secondary service, publicly funded computed tomography scanning (CT), is compared across different geographic areas in the southern end of New Zealand's South Island. Otago and Southland are New Zealand's two most southern provinces. The Otago District Health Board and the Southland District Health Board were amalgamated in May 2010 to form the Southern District Health Board (SDHB). The total population of the SDHB region is 305,000. (87) The region includes two urban centres, Dunedin (population 127,300) and Invercargill (population 51,600). (88) Almost all of the medical specialists in this region are based in one of these two centres. Invercargill and Dunedin Public Hospitals provide base hospital services for Southland and Otago respectively and Dunedin Public Hospital also provides some tertiary services for the whole region.

There are five hospitals in the region that are defined as rural by the New Zealand Medical Council; Oamaru, Dunstan (near Alexandra), Queenstown, Gore and Balclutha. The New Zealand Medical Council defines a rural hospital as “a hospital staffed by suitably trained and experienced generalists, who take full clinical responsibility for a wide range of clinical presentations. While resident specialists may also work in these hospitals, cover is limited in scope or less than full time.”

At the time of this study there are three public diagnostic CT scanners in the SDHB region. The urban centres, Dunedin and Invercargill, each have one. The third is located in Oamaru and was the region’s only rural CT. All scanners have similar capabilities but because there is no resident radiologist in Oamaru, the Oamaru scanner is not used for invasive CT guided procedures. The regions only private CT scanner is in Dunedin. Data for this scanner was not available and is not included in this study. CT scanners are still uncommon outside urban centres in New Zealand. In 2010 only two New Zealand rural hospitals had on site CT; Oamaru was the smaller of these.

Access to CT for rural patients is currently a topical issue in southern New Zealand. A CT scanner was recently installed at Dunstan Hospital (April 2013) and other rural hospitals may follow suit.

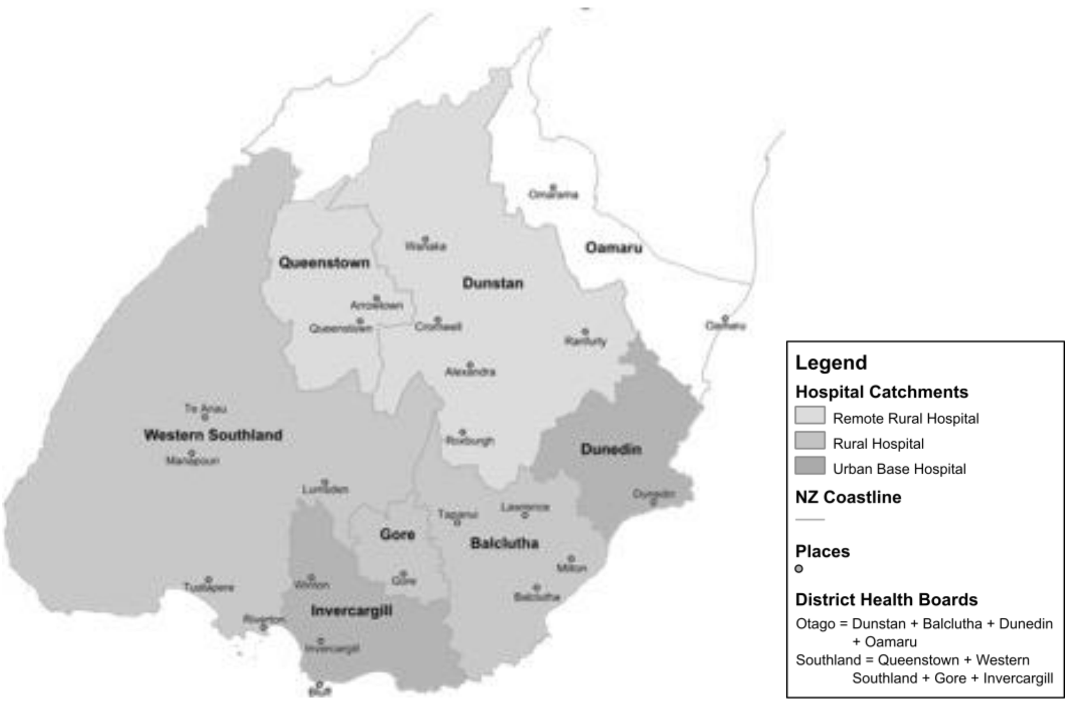
The aim of this study is to determine whether there is significant geographic variation in the utilisation of CT scanning in the SDHB region. Then if present, to measure the magnitude of the variation for different referral and procedure subgroups.

Method

We obtained data from the radiology departments at Dunedin, Invercargill and Oamaru hospitals, for all the publicly funded CT scans performed in the region from April 2007 to March 2008, and from January to December 2010. These two periods were chosen because they straddle the commissioning of the CT scanner in Oamaru (April 2008). Data collected included domicile (normal residential address of scanned patients), demographic data (age and ethnicity), procedure(s), date of referral and scan (so waiting times could be analysed) and referral source (inpatient, specialist outpatient clinic or emergency department). Scan refers to a single CT scan appointment. Procedure refers to the region or organ system being scanned. More than one procedure is often included in a single scan. Resident population statistics in Otago-Southland during 2007, 2008 and 2010 were obtained from Statistics New Zealand.

Emergency department (ED) referrals are acute referrals requested for patients who have not yet been admitted to hospital. ED referrals can be made by doctors working in either base hospital or rural hospital EDs. Doctors working in rural hospitals can organise an urgent base hospital CT on an ED patient under their care. Patients are then transferred to the base hospital for the scan and, depending on the result, discharged, admitted to the base hospital or transferred back to the rural hospital for admission. It is however more common, and often simpler, for the patients to be transferred to base hospital EDs, who will then take over responsibility for their care, including arranging CTs.

Figure 3: Hospital catchments in Southern District Health Board region



The analysis is based on the rural hospital catchments shown in Figure 1. Each of the SDHB rural hospitals has a defined catchment area based on census meshblocks (groupings of domiciles used by Statistics New Zealand). These catchments reflect the dominant model of secondary healthcare. Patients resident within the catchment of rural hospitals who present with an acute medical problem are managed, at least initially, by generalist doctors at their local rural hospital. Because of the mountainous geography and limited roading in the region patients seldom travel to health facilities in another rural hospital catchment for treatment. However travel to Dunedin or Invercargill for base hospital care is a common occurrence. These hospital based catchments are used by the SDHB for organising and contracting secondary health services throughout the region.

The Dunedin and Invercargill base hospital catchments are defined by the boundaries of the neighbouring rural hospital catchments and not by their territorial authority city boundaries. Domiciles outside a rural hospital catchment are ascribed to the nearest urban base hospital. The one exception is Western Southland. While this rural area has no rural hospital it has many of the features of the other rural catchments. When patients become acutely unwell they do not routinely travel to the Invercargill hospital emergency department but instead visit local general practitioners who maintain a comprehensive 24 hour acute service similar to that provided by a rural hospital ED. The boundaries of the Western Southland catchment were similarly based on census meshblocks and drawn up after talking to local general practitioners about the effective geographic limits of their practice catchments.

In a single year there were insufficient numbers of scans in many of the procedure and referral source subgroups to allow comparison at these levels between catchments. To overcome this problem, data from the two study periods were combined and catchments were grouped into urban base hospitals (Invercargill and Dunedin), rural hospitals (Balcutha, Gore and Western Southland) and remote rural hospitals (Queenstown and Dunstan). Queenstown and Dunstan rural hospitals are 190km from Invercargill and Dunedin respectively. Oamaru is 112km, Balcutha is 80km and Gore 158km distance from their nearest base hospital. Although the largest town in Western Southland, Te Anau, is located 157km from Invercargill, the majority of residents in this catchment live within a 90km radius of Invercargill. Because Oamaru changed from a catchment without a CT to one with a CT between the study periods, with a consequent major change in its CT utilisation, it was excluded from the procedure and subgroup analyses.

Scans performed on patients normally resident outside the SDHB region were excluded.

Crude scanning rates were calculated for each catchment population. Rates were also calculated by referral sources and by procedures. Age standardised results were calculated by disaggregating crude rates for each catchment by age groups and by period. The standard population used was the combined population in all catchment areas in both periods.

A separate analysis was undertaken for the ≥70 years age group. Results of this were expressed as a crude rate that was not age-adjusted. A preliminary analysis was undertaken to confirm that the age distributions of the ≥70 years populations were similar for all the catchments and that crude rates would therefore be comparable.

All the rates reported in this paper are the number of scans or procedures per 1000 residents per annum. We performed a survival analysis to compare waiting times.

Ethics approval was obtained from the Ministry of Health Southern Regional Ethics Committee (LRS/10/EXP056).

Results

Patients normally domiciled in the SDHB region in the 24 months of the study received 20,391 scans. Of these, 20,316 scans were included in the final analysis: 75 (0.4%) scans were excluded because of lack of accurate domicile data. This occurred because of changes to census mesh blocks. Most of the excluded scans (52) were for patients living in or close to Invercargill.

Table 12: Total scans and scanning rates for total population and > 70 yrs

Catchment	2007/08 Total Pop.	Scans[1]	Rate[2]	Scans ≥ 70yrs[3]	Rate ≥70 yrs[4]	2010 Pop.	Scans[1]	Rate[2]	Scans ≥ 70yrs[3]	Rate ≥ 70yrs[4]
Oamaru	20620	538	23.0 (21.0-5.1)	266	90 (80-101)	20735	1176	45.6 (43.0-48.2)	554	177 (164-191)
Balclutha	17236	494	30.7 (28.0-3.4)	200	122 (106-138)	17480	601	34.1 (31.5-36.8)	257	148 (131-165)
Dunstan	25682	592	21.9 (20.2-23.7)	258	94 (84-106)	27480	754	25.2 (23.5-27.0)	294	98 (87-109)
Queenstown	17529	242	19.9 (16.9-22.1)	67	83 (65-104)	18560	312	22.3 (19.8-24.9)	76	84(66-103)
Gore	13187	424	30.5 (27.7-33.4)	210	130 (114-148)	13285	558	38.5 (35.3-41.6)	219	129 (114-146)
Western Southland	13778	345	30.1 (27.0-33.2)	146	148 (126-172)	13860	417	32.8(29.7-35.9)	171	162 (139-185)
Invercargill	66005	2294	35.3 (34.0-36.7)	1035	156 (148-165)	67015	2740	40.1 (38.7-41.5)	1232	175 (166-184)
Dunedin	124046	3992	33.2 (32.2-34.2)	1797	150 (143-156)	126360	4837	38.9 (37.9-40.0)	2156	154 (133-177)

[1] Total scans per annum for all age groups
[2] Scans per 1000 residents age adjusted with 95% confidence intervals
[3]Total scans per annum on residents ≥ 70 yrs
[4]Scans per 1000 residents ≥ 70 years with 95% confidence intervals. Crude rates that have not been age adjusted
Pop. = population

Differences in CT utilisation rates between catchments are shown in Table 12. In 2010 all rural hospital catchments, except Balclutha, had statistically significant lower CT scan rates than the urban base hospital catchment to which they normally refer patients. The rate for the Dunedin base hospital catchment was 1.5, 1.4 and 1.1 times that that of Dunstan, Oamaru and Balclutha rural hospital catchments respectively. The rate for Invercargill was 1.8, 1.2 and 1.4 times that of Queenstown, Gore and Western Southland respectively. Similar disparities were identified when the analysis was confined to the ≥70 years age group. With the exception of Oamaru, the disparities in scanning rates between catchments changed little between the study periods.

Table 13: Rates by catchment groups, referral source and procedure

	Remote Rural Hospital Catchments	Rural Hospital Catchments	Urban Base Hospital Catchments
All Scans*	22.5 (21.5-23.5)	32.2 (31.1-33.4)	36.7 (36.1-37.2)
Referral Source:			
Emergency Dep.(ED)*	5.1 (4.7-5.6)	7.9 (7.3-8.6)	10.9 (10.6-11.3)
Inpatient*	8.4 (7.7-9.0)	10.8 (10.1-11.4)	11.8 (11.4-12.1)
Specialist Outpatient*	8.9 (8.3-9.5)	13.2 (12.5-14.0)	13.9 (13.5-14.2)
Procedure:			
Abdomen#	8.0 (7.4-8.6)	12.8 (12.1-13.5)	12.2 (11.8-12.5)
Chest#	5.6 (5.1-6.1)	7.5 (7.0-8.1)	7.8 (7.5-8.1)
Head#	6.7 (6.1-7.3)	9.3 (8.6 -9.9)	12.5 (12.2-12.9)
Pulmonary angiogram#	1.0 (0.8-1.2)	1.4 (1.2-1.7)	2.1 (1.9-2.2)
Cervical Spine#	1.3 (1.1-1.6)	2.1 (1.8-2.4)	1.9 (1.8 -2.1)
Kidney/Urogram#	0.6 (0.4-0.8)	1.3 (1.0-1.5)	1.6 (1.5-1.8)
ED referred Head scan#	2.3 (1.9-2.6)	3.5 (3.1-3.9)	5.6 (5.4-5.9)
ED referred kidney #	0.3 (0.2-0.4)	0.5 (0.3-0.6)	1.1 (1.0-1.2)
ED referred CTPA#	0.3 (0.2-0.4)	0.5 (0.4-0.7)	1.0 (0.9-1.2)
Inpatient CTPA#	0.6 (0.5-0.8)	0.8 (0.6-1.0)	1.0 (0.9-1.1)

*Scans per 1000 residents per annum age adjusted (95% confidence intervals)
#Procedures per 1000 residents per annum age adjusted (95% confidence intervals)

ED referrals accounted for almost half (49%) of the total difference in scan rates between remote rural hospital catchments and urban base hospital catchments though they constituted only 28% of total referrals.

More than one (and up to four) procedures were included in 23% of scans. We therefore analysed 25,868 procedures. Disparities between catchments were evident across a range of procedures but among procedures commonly performed, disparities were greatest for head scans, kidney scans and CT pulmonary angiograms.

Ethnicity data were available for 96.4% of patients scanned. Both Māori (8% of population and 4.5% of scans) and Pacific Islanders (1.6% of population and 0.9% of scans) were scanned at a lower rate than other ethnic groups.

Scanning rates are closely associated with age: 44% of scans were for people aged 70 or older, who represent only about 10% of the population. The demographics of the populations in the catchments varied. The Queenstown catchment in particular, was considerably younger than other catchments.

The number of scans performed increased between the two study periods by 27%, equivalent to 9% per annum. The increase in the Oamaru catchment stood out from the others. Following the commissioning of a local CT scanner the number of scans performed on residents of this catchment rose by 119%, a 98% increase in the age adjusted scanning rate.

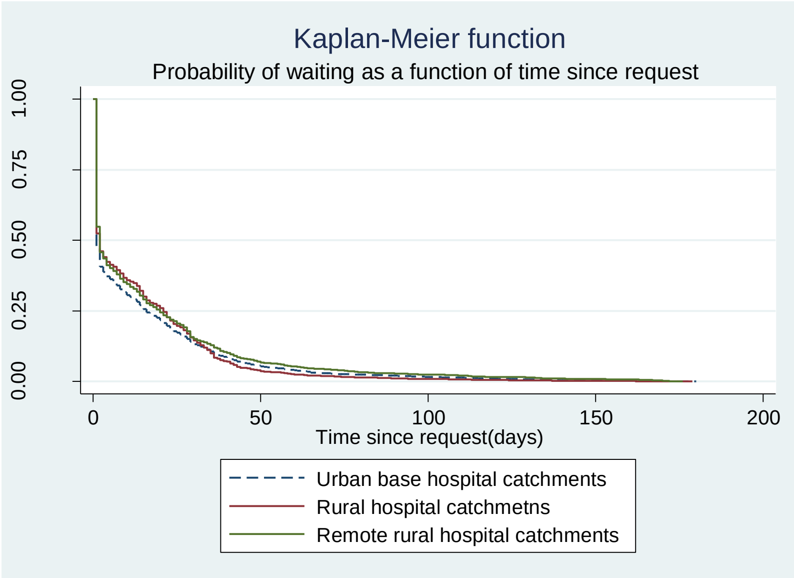
The percentage of patients failing to keep their appointments was low (1.2% overall, urban base hospital catchments 1.2%, remote rural/rural hospital catchments combined 1.1%).

Waiting times decreased for the Dunedin scanner (mean 17.8 days (2007/08); 13.4 days (2010)) and increased for the Invercargill scanner (mean 8.9 days (2007/08) to 10.8 days (2010)) between the two study periods. The mean waiting time for the Oamaru scanner in 2010 was less than one day.

Dunstan was the only catchment with a statistically significant longer mean waiting time than the catchment of its referral base hospital; Dunstan 18.6 days (95% CI 16.4-20.9) and Dunedin 14.8 days (95% CI 14.1-15.5). Mean waiting times for other catchments were Balclutha 14.8 days (95% CI 12.9-16.6), Oamaru 11.2days (95% CI 9.7-12.7), Gore 11.2 days (95% CI 10.3-12.1), Invercargill 9.4 days (95% CI 9.0-9.8), Queenstown 9.5 days (95% CI 8.1-11.0) and Western Southland 10.2 days (95% CI 9.0-10.9).

Survival analysis as represented in Figure 4 illustrates the probability of still being on the waiting list over time.

Figure 4: Relationship between waiting time and hospital catchment group



Discussion

We found CT scanning rates of between 19.9 and 45.6 per 1000 population per year in this study of CT utilisation in southern New Zealand. These rates appear low by international standards. In 2001 the rate for Ontario was approximately 66 scans per 1000 residents per year and growing by 11% per annum. (89) Norwegian rates in 2002 ranged from 56 per 1000 residents / year in a remote rural area to 216 in Oslo. (90) Care does need to be taken when making ***c***omparisons with other published CT scanning rates. Overseas figures may include private scans, be for populations with different age profiles or use different standard populations for age adjustment.

The geographic variation in the utilisation of CT we have identified in the Southern District Health Board (SDHB) region is large. Adjusted for age we found that the overall CT scanning rate for the urban base hospital catchments was 63% higher than the rate for remote rural hospital catchments and 14% higher than the rate for rural hospital catchments (table 13). These variances are greater than reported in Ontario (rural rate 8% lower than urban rate) but less than the Norwegian figures cited above. (89, 90)

Because mean waiting times are heavily influenced by a small number of patients with long waiting times, the probability of still being on the waiting list over time is a better measure of clinical impact of waiting times. Kaplan-Meier survival analysis as presented in Figure 4 suggests that patients in the remote rural and rural catchments are not being disadvantaged by longer wait times for CT than those in urban base hospital catchments.

The number of scans that were excluded because of inadequate domicile data was small and unlikely to impact on the final results. Further, because those excluded were mainly from urban areas, their exclusion would reduce rather than inflate the disparities we demonstrated.

The sensitivity of scanning rates to patient age and differences in the demographics of catchment populations confirmed the importance of calculating age adjusted rates.

The only new scanner installed during the study period was in Oamaru (where scanning rates more than doubled following the scanner becoming locally available). However scanning rates increased in all catchments. This was achieved by increased efficiencies and operating hours for the scanners in Invercargill and Dunedin.

There are a number of potential reasons for geographic variation in healthcare utilisation. Research undertaken in the United States identified large geographic variation in the utilisation of healthcare services. They concluded that this was a result of service availability and variation in clinical practice, with differences in disease burden and patient migration having only a minimal effect. (42) We can think of no reason why there should be different rates of disease between the communities we studied. Variation in service availability and clinical practice are the most likely explanation for the disparities in CT scanning rates we observed.

Clinical practice may vary because acceptable alternatives to CT are available in rural hospitals. For example rural patients presenting with a head injury are often still managed by admission and serial observation and rural patients presenting with renal colic may be offered an intravenous urogram rather than transferred for a CT urogram. However this can explain only some of the variation in practice. There is for example no locally available diagnostic alternative to CT pulmonary angiogram (CTPA) for investigating potential pulmonary embolus that could explain the more than twofold difference in the utilisation of this procedure between remote rural hospital catchments and urban base hospital catchments.

There are considerable differences in the way that rural and urban urgent outpatient and inpatient services are configured in the SDHB region and this may impact ED referred scan rates in particular. In rural hospital catchments acute care is provided almost exclusively by experienced generalist doctors working in primary care and rural hospitals. Rural general practitioners are more likely than urban general practitioners to act as “gate keepers” for acute secondary care. In the urban hospital catchments much of the acute care is provided by junior doctors working under the supervision of specialists in base hospital emergency departments and wards, with easier access to CT.

The merits of specialist vs generalist care, and in particular the role of primary care and EDs in the provision of urgent care, is being debated both in New Zealand and overseas. (91-92) Much of the debate centres on the impact these models of care have on the overall use of healthcare resources. This paper can add only a limited amount of information to this debate. It does appear that many rural generalists in the SDHB region have a higher threshold for ordering a CT and are therefore practicing with higher levels of diagnostic uncertainly than their urban hospital colleagues. At the same time, the Oamaru data demonstrates that when CT becomes locally available rural generalists will alter their threshold for ordering a CT and utilisation rates will increase considerably. In 2010, after a CT was installed in Oamaru Hospital, Oamaru had the highest scanning rate in the region. This supports the hypothesis that having the service locally available is the more important driver of utilisation rates.

We found significant variation in specialist outpatient referrals for CT scans. Rural patients are seen by the same specialists as urban ones, either by travelling to urban outpatient clinics or the specialists travelling to rural clinics. One possible explanation for this variation is that specialists also have a different threshold for ordering a scan when they know it involves a potentially unwell or elderly patient having to travel a significant distance. Another possibility is that rural patients do not access specialist outpatient clinics as often as their urban neighbours. A study similar to this, examining the utilisation of specialist outpatient clinics, would resolve this.

This study was not designed to examine ethnic disparities although ethnicity data were collected. Rates have not been adjusted for different age distributions in different ethnic groups. Doing so would still not allow an accurate assessment of equity of access because of differences in disease burdens for any given age group between different ethnic groups in

New Zealand. The ethnicity data collected by the SDHB may be less accurate than that collected on census forms, making the numerator unreliable, and further complicating our ability to make comparisons between ethnic groups. (93) However the differences between ethnic groups that have been identified are of concern and should be evaluated further. The health status of Māori and Pacific Islanders living in New Zealand and their access to health services is known to be inferior to that of other ethnic groups. (94-95) Improving the health status of Māori and Pacific Islanders is an important New Zealand Government health policy priority. (96-97)

This study did not examine the impact of socioeconomic variables. Combinations of rurality and socio-economic deprivation have been shown to increase health access inequalities in other settings. (98) It is possible the disparities we have identified in the utilisation of CT within the SDHB region could be even greater for rural communities elsewhere in New Zealand with higher levels of socioeconomic deprivation than in the SDHB region. Future studies should consider the impact of rurality and socio-economic deprivation on the utilisation of secondary healthcare services that necessitate patients travelling to access them, often at their own expense.

This study was not designed to determine whether variation in the utilisation of CT results in differences in health outcomes although this has important implications for equity of service provision to more remote populations and/or the efficiency of the predominant model of care. It cannot be assumed that rural patients are disadvantaged by lower scanning rates, even when these rates are low by international standards. An examination of individual patient scan results to determine the number of positive and negative results, for CTPAs for example, would allow an estimate to be made of the number of diagnoses being missed as a consequence of the lower scanning rates in rural areas and would be a useful first step towards answering this question.

Conclusion

CT scanning rates across the entire SDHB region appear to be low by international standards. The remote rural hospital catchments of this region have even lower scanning rates. The reasons for these disparities and even more importantly their impact on health outcomes are unclear and need further evaluation. If the disparities reflect underservicing in rural areas there are implications for poorer health outcomes and inequitable healthcare delivery.

-End of published manuscript-

Addressing the evaluation framework

This study aimed to establish the extent of rural-urban disparities in access to a health service (prior to the introduction of a rurally-based service). It therefore differs from the majority of the studies in this thesis in that it is not an evaluation of a rurally-based diagnostic service, and therefore does not specifically address the performance measures in the Reeve rural service evaluation framework. The exception is the *appropriateness* of a rural CT service (which is evaluated more fully in chapter 4). By demonstrating significant under-servicing (relative to urban rates prior to the service being established), this study identifies a health inequity that helps justify establishing a rural service. Identifying an unmet health need is an indicator that establishing a local service is *appropriate*, a performance measure in the process domain of the evaluation framework.

Addressing background issues

This study highlights two important background issues to the thesis that were raised in the introduction: NZ rural health data; and urban-rural profiles.

Data on rural-urban disparities in access to health services in NZ:

As indicated in the introduction, NZ does not routinely collect data on diagnostic service utilisation and does not report urban vs. rural comparisons in access for any health services. This makes it difficult to undertake this type of study because the data cannot be easily drawn from the routinely collected national health databases. Instead, the data for this study had to be obtained directly from individual radiology providers. The patient's addresses were derived from the national health index numbers and then used to allocate patients to meshblocks.

These data problems help explain why so few studies of this type have been undertaken in NZ, and why we have not used utilisation rates as a measure of access for other health services studied in this thesis (with the exception of limited data on ETT utilisation). When considering other services, we have instead provided a simple description of the availability of the service as an indicator of access; i.e. described the distance patients need to travel to access the service and the times at which the service is available.

Urban-rural classifications:

This study used detailed local knowledge about hospital catchments and patient flows to accurately identify the population receiving rural health services at the meshblock level. In our view, the accuracy with which this process identified the population accessing rural health services, is a strength of the study. At the same time, the reviewers for the international journal that published this paper were surprised that we had not used a nationally recognised rural-urban classification for the analysis and took some convincing that the method we adopted was, in fact, the best one available in the circumstances. The large rural-urban disparities we identified, contrasted with the nationally-collected data that was available. It was these issues that prompted us to question the urban-rural classifications being used in NZ. (17, 20, 27) This is discussed in detail in the introduction to the thesis. Because the classification used in this study was heavily reliant on local knowledge and was very time consuming, it would not be a practical method for routine use when analysing data at a national level using major health data collections.

Chapter 3: The use of CT in the management of minor head injuries in Queenstown

Context Statement

Research question: *'Do rural vs. urban differences in access to diagnostic services translate into differences in health outcomes?'*

Having identified disparities in access to CT for rural people, the obvious next question is whether or not this results in differences in treatment that are then manifested as poorer health outcomes. This study does not address *mortality* or *morbidity* outcomes directly, but it attempts to shed some light on them by determining the extent to which the large differences in access to CT identified in chapter 2 are influencing adherence to evidence-based national clinical guidelines.

Specifically, the study aims to "investigate adherence to the New Zealand Traumatic Brain Injury guidelines for patients in Lakes District Hospital with minor head injury over the years 2013–2015". Lakes District (Queenstown) Hospital was one of the 'remote' hospital catchments identified in chapter 2 as having much lower rates of CT scanning than its urban referral centre.

Keys, J. Venter, L. Nixon, G. The use of CT in the management of minor head injuries in Queenstown. J Prim Health Care 2017; 9(2):162–166. doi:10.1071/HC16029

Introduction

The most recent estimate of the usually resident population of Queenstown and suburbs (excluding Wanaka) is 27,492 people. (99) It is one of the fastest growing districts in New Zealand. Queenstown hosts large numbers of domestic and international tourists, accounting for 9% of all commercial accommodation nights in New Zealand. (100)

Lakes District Hospital is situated 183 km from the base hospital in Southland and 279 km from Dunedin Hospital, which provides neurosurgical and intensive care services. Lakes District Hospital, a 10-bed rural hospital staffed mainly by vocationally registered rural hospital doctors, has an emergency department. On-site imaging is limited to standard radiographs and point-of-care ultrasound. The nearest computed tomography (CT) scanner is at Dunstan Hospital, a rural hospital that is 80km distant. Most weeks the Dunstan Hospital CT scanner operates on weekdays during working hours. Ambulance transport for hospital transfers outside of working hours can be challenging to organise, and adverse weather can hinder helicopter evacuation.

Queenstown is known for its adventure sports (particularly snow sports and mountain biking) and hospitality. Binge drinking and assaults are common. Trauma forms a large portion of the workload of Lakes District Hospital. In 2014–15 the New Zealand Accident Compensation Corporation (ACC) reported 1351 concussion or brain injury claims in Otago, which represents 10% of all such injuries reported in New Zealand over the same period, despite

Otago containing only 5% of the New Zealand population. (101) Absent any other difference between Otago and the rest of New Zealand that might explain such excessive numbers, it seems likely that it may be due to the combination of youth, sport, alcohol, and high visitor numbers in Queenstown. It is not possible to confirm it from ACC data.

More than 10 years ago, Stiell et al. produced and validated the Canadian CT Head rule, which has high sensitivity and reasonable specificity for the diagnosis of significant intracranial injury in minor head injury. (102) The Canadian CT Head rule has been adapted for use in New Zealand by the New Zealand Guidelines Group. (103)

This study aimed to investigate adherence to the New Zealand traumatic Brain injury guidelines (Table 14) for patients in Lakes District Hospital with minor head injury over the years 2013–2015.

Table 14: Excerpt from the New Zealand Traumatic Brain Injury Guidelines

CT scans should be immediately requested for adults who have sustained a head injury, if they have any one of the following risk factors:

- any deterioration in condition
- a Glasgow Coma Scale score of less than 13 when assessed, irrespective of the time elapsed since the injury
- a Glasgow Coma Scale score of 13 or 14 two hours after the injury
- a suspected open or depressed skull fracture
- any sign of basal skull fracture (haemotympanum, 'panda' eyes, cerebrospinal fluid, otorrhoea, Battle's sign)
- post-traumatic seizure
- focal neurological deficit
- more than one episode of vomiting
- amnesia for more than 30 minutes for events before the injury.

CT scanning should be immediately requested for adults with any of the following risk factors who have experienced an injury to the head with some loss of consciousness or amnesia since the injury:

- age 65 years or older
- coagulopathy (history of bleeding, clotting disorder, current treatment with warfarin)
- high-risk mechanism of injury (a pedestrian struck by a motor vehicle, an occupant ejected from a motor vehicle, or a fall from a height of greater than one metre or five stairs).

Methods

Using the emergency department's electronic patient management system, all patient contacts coded with a primary diagnosis of head injury, concussion, or scalp laceration were downloaded. Young people aged ≤15 years were excluded, as were patients who were returning for review. An excel spreadsheet was built to include details of each patient's age, sex, mechanism of injury, and the presence of any of the 'high risk features' that the New Zealand Guidelines identify as indications for an immediate CT head scan. Individual patient notes were then searched. If a high-risk feature was not noted as present in either electronic medical or nursing notes it was assumed to be absent. Following data collection, a group of patients who fulfilled the criteria for the diagnosis of minor head injury (Glasgow Coma Scale (GCS) 13-15) was obtained by excluding patients defined as having a head injury that was major (GCS < = 8), moderate (GCS 9-12) or minimal (no change in mental status).

Skiing or fast mountain biking, jumping a bike, skis or snowboard, and damaging a helmet were judged as high-risk mechanisms of injury, along with more standard descriptions.

Results

During 2013-15, 883 patients with head injuries were seen at Lakes District Hospital, including 657 patients aged ≥16 years. The average age of adult patients was 37 years: 63.8% were male. Of all adult head injuries, 41% occurred while participating in sport, 28.5% were caused by falls, 23% were alcohol related, and 9.44% were the result of assault. Nineteen (2.9%) head injuries were moderate or severe, 481 (73.2%) were minor, and 157 (24.0%) minimal. Of 481 patients with minor head injury 280 (58%) had high risk features documented in their clinical record that would mandate immediate CT head according to the

New Zealand Guidelines. The most common high-risk features were high energy mechanism of injury (162 patients), antegrade amnesia (107 patients) and GCS < 15 at 2 h post injury (63 patients). CT head scans were performed on 66 (23.6%) of 280 patients with minor head injury who met NZ guideline criteria for CT scanning.

Discussion

Less than one in four Lakes District Hospital patients presenting with a minor head injury who met New Zealand guidelines criteria for an immediate CT head scan actually had a CT head performed, which is consistent with the previously demonstrated per capita public CT scanning rate for Queenstown residents which is 57% of nearby larger centres. (31)

Retrospective chart audits have limitations, including being prone to bias when the data abstraction is undertaken by a single investigator. (104) The present study, however, is more likely to underestimate rather than overestimate the number of patients with high risk features who did not receive CT head scans. Clinical notes did not usually refer specifically to Guideline CT criteria and it was often not possible to determine the GCS two hours post-injury as the time of injury was not recorded. Unless there was clear evidence in the notes that a high-risk feature was present, it was assumed to be absent. It is also likely that the study underestimated the total number of head injuries because it did not capture head injuries that occurred in addition to another primary injury.

Fifty percent of patients attending Lakes District Hospital are not local residents and information on medium- and long-term outcomes is not contained in the local clinical record. It is therefore not possible to ascertain individual patient outcomes. However, the New

Zealand Guidelines are adapted from the Canadian CT Head rule which has been validated in multiple different settings. (105) Because practice at Lakes District Hospital is at such variance with these guidelines it is likely that patients with clinically important intracranial injuries are being missed.

The Canadian CT Head rule is over 99% sensitive for minor head injuries requiring neurosurgical intervention and 98% sensitive for all significant intracranial injuries. (106) One Canadian CT Head rule validation study revealed neurosurgical intervention rates of 0.4% (GCS 15 at first assessment) and 1.3% (GCS 13) with clinically important intracranial injury rates of 7.5% (GCS 15) and 24.5% (GCS 13). (105) Twenty percent of patients in the initial validation study were GCS 15 at initial presentation. In comparison, 22.5% of patients in our study cohort remained <GCS 15 at two hours after presentation, suggesting that their head injuries were at least as severe as injuries in the validation study.

Clinically important intracranial injury is defined as any positive CT finding (excluding minimal contusions or haematomas) that would usually require hospital admission and neurosurgical follow-up. (107) Although neurosurgical intervention is not required, studies have shown that these patients have delayed recovery, significant ongoing differences in neurocognitive function and persistent MRI findings compared with patients with normal CT scans. (108-110) Recurrent concussions are associated with delayed resolution of symptoms and long-term effects such as mental health disorders and memory impairment. (111, 112) Many patients in the present study may be at risk of recurrent sport or alcohol related head injuries and may have benefitted from risk modification advice or referral to head injury rehabilitation services.

Conclusion

CT scanner in Queenstown

Technological advances have made CT cheaper and easier to provide in rural areas. Services have been successfully introduced into other rural centres with comparable resident populations. These have overcome access disparities without over-servicing. (89, 113) Particular features of Queenstown further strengthen the argument for a CT scanner there: its distance from tertiary services, the rapidly growing resident population and the large number of visitors who enjoy the town's high-risk adventure sports and party culture.

Rural Health inequalities:

This paper provides further evidence that rural New Zealanders have worse access to medical imaging, which has impacts on clinical care. Rural New Zealanders also experience worse access than urban people to ambulance services, primary care, pharmacies, and mental health services. (114) People living in rural communities in Australia, Canada and the United States have poorer health outcomes than people living in urban areas. (115-117) It is not clear whether these health outcomes are related to environmental differences, health behaviours, or access to medical care, although worse access to medical care for rural people has been also been documented in these countries. (118, 119) It has been suggested that New Zealand's urban/rural health disparities may be greater than currently appreciated. (27)

Guideline development:

The New Zealand Head Injury Guideline offers an 'alternative management approach for rural centres without access to CT.' (120) It suggests that only patients with moderate or severe head injuries are immediately imaged, and all others who meet usual criteria for scanning are discussed with a neurosurgical centre. It is unclear if there is evidence to support this alternative approach. It is also our experience that usual advice from the neurosurgical centre is to ‘scan according to guidelines’. This is unfortunately often not practical in rural settings.

The current study highlights a gap between the realities of practice in rural New Zealand and current clinical guidelines. The lack of evidence on how best to manage minor head injuries where there is no ready access to CT continues to make the rational management of these patients challenging. It is important to carefully consider all healthcare contexts when guidelines are developed. Relevant research should be encouraged, and rural clinicians should be included on clinical guidelines development committees.

-End of published manuscript-

Addressing the evaluation framework

In this chapter we have still not reached the point in the thesis in which we evaluate a rural diagnostic service. Instead, this study evaluates the *appropriateness* of a rural CT service (that is evaluated in chapter 4) by generating additional evidence on the need for the service. It does this by demonstrating a health need that goes beyond inequity in access to a diagnostic test to include a consequential inequity in adherence to evidence-based clinical guidelines.

The principal finding of this study was that fewer than one in four patients presenting with a minor head injury to Lakes District Hospital, who met NZ guidelines criteria for an immediate CT head scan, actually had a CT head scan performed. This is consistent with the low CT scanning rate (57% of that of the nearby larger centre) demonstrated for this community in chapter 2. This small retrospective observational study – essentially an audit of clinical practice – was neither designed nor powered to demonstrate a difference in patient outcomes, but it raises the possibility of inequitable health outcomes. The 'gold standard' (NZ Head Injury Guidelines) used in the audit are based on the 'Canadian CT head rule' – a set of clinical guidelines that has been validated in multiple contexts. It is therefore quite plausible that the very poor adherence to evidence-based guidelines identified in this study could result in poorer patient outcomes.

The Reeve evaluation framework identifies *mortality*, *morbidity*, *equity* and *wellbeing* as performance measures in the outcomes domain. As discussed in the introduction and in chapter 2, morbidity and mortality are traditional outcome measures, but because they are frequently small, rural health studies seldom have the power to address these outcomes. This makes equity an even more important rural health service performance outcome measure, one for which it is easier to demonstrate statistically significant differences. That is, it is easier to demonstrate an urban-rural inequity in access into CT scanning than it is to prove that this inequity is resulting in higher mortality or increased morbidity. However, this study gets closer to suggesting that the inequity identified in access to a diagnostic test could be resulting in poorer patient outcomes (morbidity and mortality) than the other studies in the thesis.

Chapter 4: The impact of a rural scanner in overcoming urban vs. rural disparities

Context statement

Study questions: *Does establishing a rural service overcome the inequity in access faced by the rural population? Is the service efficient?*

This is the first paper in the thesis to evaluate a rurally-based diagnostic service and thereby address the primary aim of the thesis of improving health outcomes for rural populations by improving access to diagnostic services.

The study in chapter 2 demonstrated a significant inequity in access to CT for the Oamaru rural community, along with others in the region, relative to nearby urban areas. Using local funding, Oamaru became the first rural community to establish its own CT service. This provided an opportunity to answer the second research question; specifically, to what extent did the Oamaru rural service overcome the inequity in access? Data was therefore collected on CT utlisation in the period immediately before and after the Oamaru CT was installed.

The study also addresses indicators for the efficiency of the service. CT scanning is an expensive service with respect to capital equipment, maintenance, and specialist staff to undertake and report the scans. The management at Oamaru hospital reported that base hospital management expressed concern that the increased availability of CT in Oamaru would result in over-servicing and unnecessary CT scans being performed. The study therefore looked for evidence of over-servicing. The discussion also includes information obtained from Oamaru hospital management about the way the service was structured, and indications of its relative efficiency, including accessing the necessary medical radiation technologist (MRT) and radiologist skills.

When the provision of a rural diagnositic service is dependent on generalist health professionals undertaking tasks that would in the city be perfomed by specialists, quality and safety become important considerations. This is less of an issue with modern CT scanners and teleradiology. Oversight of the Oamaru service, including the reporting of all scans, is successfully undertaken by urban-based radiologists. Therefore, less consideration is given to indicators of quality in this study than to the other studies in this thesis.

Nixon G, Samaranayaka A, de Graaf B, McKechnie R, Rodwell P, Blattner K. The impact of a rural scanner in overcoming urban versus rural disparities in the utilisation of computed tomography. Aust J Rural Health. 2015;23(3):150-4.

Introduction

In April 2008 Oamaru Hospital became the smallest public hospital in New Zealand to install a computed tomography (CT) scanner. CT scanners are still uncommon outside urban centres in New Zealand. In 2008 only one other New Zealand hospital that meets the NZ Medical Council definition of a rural hospital, Thames Hospital, had an onsite CT scanner. Thames is a larger hospital than Oamaru, with 54 beds and some on site surgical services.

There is limited published data on rural versus urban disparities with regard to access to complex diagnostic investigations like CT and even less on the impact these disparities might have on health outcomes. We were able to find only one other study that examined the impact of a rural CT scanner on scanning rates. The commissioning of a rural CT scanner in a rural Ontario community in Canada saw scanning rates increase, but not surpass those of the neighbouring urban centre. (89)

The aim of this paper is to evaluate the extent to which the Oamaru scanner has improved access to CT scanning for this rural community by comparing scanning rates over time and with those of neighbouring rural and urban communities.

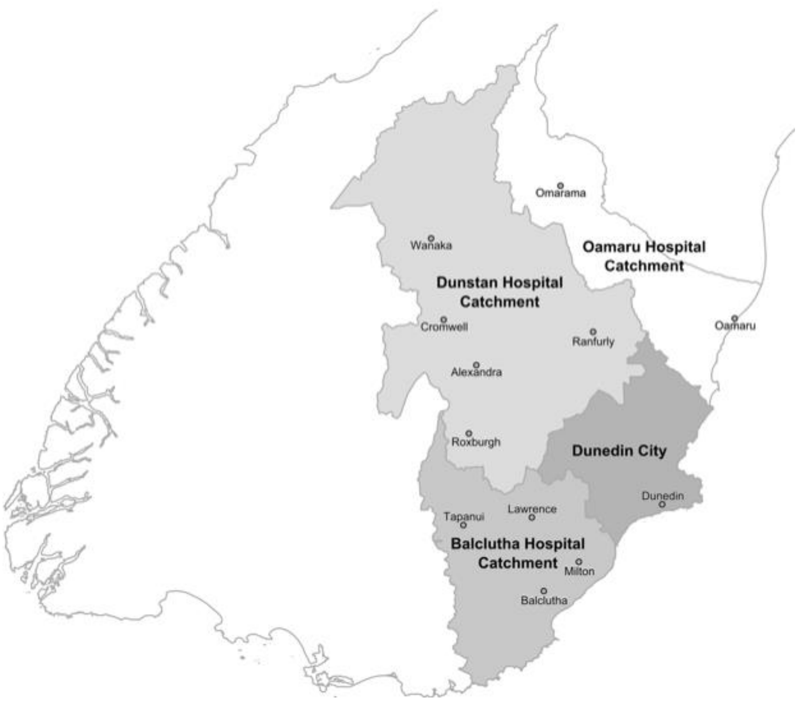
Methods

Setting

Oamaru is a 30-bed rural hospital that serves a community of 22,000 in the South Island of New Zealand. Medical services include an emergency department, inpatient medical ward and visiting specialist outpatient clinics. Its medical workforce comprises one full time general physician, one part time emergency physician and seven rural generalists. Diagnostic services include laboratory, plain x-ray and ultrasound. There are no onsite surgical services.

The nearest base hospital is 110 km away in Dunedin. Prior to 2008, Oamaru residents had to travel to Dunedin for a CT scan. Dunedin Public Hospital provides base hospital services for the whole Otago region. There are two other rural hospitals in Otago: Balclutha and Dunstan, neither of which had onsite CT at the time of this study. When considering secondary care health services the region is divided into the recognised catchments of each of these hospitals (Figure 5). The data analysis in this paper is based on these same catchments.

Figure 5: Province of Otago, South Island, New Zealand, rural hospital catchments



Description of Service

The Oamaru scanner is staffed by the same group of medical radiation technologists (MRTs) who staff the hospital's plain x-ray service. Oamaru Hospital is fortunate in having the services of a senior MRT who has considerable prior CT experience. This MRT spent two weeks in other units with the same model of scanner. He then took responsibility for the service including the training of the whole MRT team. They now provide a 24 hour, seven day per week CT service. Some of the more complicated contrast examinations are only available during normal working hours.

Guided CT procedures that demand specialist radiologist skills are not available in Oamaru. Protocols for stroke thrombolysis have recently been developed in conjunction with base hospital specialists and it is intended to introduce this service.

The physical separation between the CT scanner and the emergency department that can be problematic in many larger hospitals is not an issue in Oamaru. The scanner is located nearby and functionally is in the same department.

Prior approval to undertake scans is sought from a Dunedin based radiologist. For non-acute scans this is done by review of the request forms. For acute scans the local MRT, or occasionally the requesting physician, discusses the appropriateness of the scan with the radiologist by phone. The same radiologist will then review the scan and provide an immediate report.

Data

We obtained data from the radiology departments at Oamaru and Dunedin Hospitals for all publicly funded CT scans from April 2007 to March 2008, and from January to December 2010-2012. Data collected included domicile (normal residential address), type of scan (procedure) and date of referral and scan (so waiting times could be analysed). The data was obtained as part of a larger study looking at geographic variation in the use of CT across the region. (31) Patient details were linked to domiciles which were then grouped into hospital catchments.

Resident population statistics in Otago from 2007 to 2012 were obtained from Statistics New Zealand. Crude scanning rates (number of scans per 1000 residents per annum) were calculated for each catchment. Scanning rates are very sensitive to age (for example 44% of scans are for people aged 70 or older, who represent only about 10% of the population), and age structures are dissimilar between catchments. Scanning rates were therefore directly age standardized by disaggregating crude rates for each catchment by age groups and by period ('dstdize' command in stata® was used for the calculation). The standard population used was the combined population in both periods.

Ethics approval was obtained from the Ministry of Health Southern Regional Ethics Committee LRS/10/EXP056.

Results

Prior to the commissioning of the Oamaru CT scanner all the rural catchments in Otago had CT scanning rates that were considerably lower than Dunedin City’s. During the 2007-08 period residents of Dunedin were 1.5, 1.4 and 1.1 times more likely to have a CT scan than those living in the Dunstan, Oamaru and Balclutha catchments respectively (Table 15). With the exception of Oamaru, these disparities increased over time. By 2012 Dunedin residents were 1.7 and 1.3 times more likely to have a CT scan than those living in the Dunstan and Balclutha catchments, respectively. Similar rural versus urban disparities were identified when the analysis was confined to the ≥70 yrs age group. (31)

Table 15: Scans per 1000 residents per annum age standardised (95% CI)

Catchment	2007-2008	2010	2011	2012
Oamaru	23.0 (21.0-25.1)	45.6 (43.0-48.2)	43.2 (40.5-45.8)	50.5 (47.6-53.3)
Dunstan	21.9 (20.2-23.7)	25.2 (23.5-27.0)	28.6 (26.1-30.4)	26.3 (24.5-28.1)
Balclutha	30.7 (28.0-33.4)	34.1 (31.5-36.8)	34.0 (31.1-36.7)	36.5 (33.8-39.2)
Dunedin City	33.2 (32.2-34.2)	38.9 (37.9-40.0)	46.3 (45.1-47.4)	45.9 (44.8-47.0)

The scanning rate for Oamaru residents almost doubled after the local CT scanner was installed. In 2010 Oamaru residents had the highest scanning rate in the region, 1.2 times that of Dunedin City. This higher rate was not sustained. In 2011 and 2012 Oamaru residents had CT scanning rates similar to those for Dunedin City.

The mean waiting time for Oamaru patients fell dramatically from 21.1 days (95% CI 17.1-25.2) in 2007-08 to 6.7 days (95% CI 5.6-7.8) in 2010. This compares to 12.6 days (95%CI 11.9-13.3) for Dunedin and 16.7 days (95% CI 14.1-19.4) for Dunstan during the same year.

Prior to 2008 all scans on Oamaru patients were performed in Dunedin. In 2010 after commissioning the local scanner, 36% of all scans performed on Oamaru catchment patients were still being performed in the base hospital scanner in Dunedin. This figure was 51% in 2011 and 50% in 2012.

There was a modest fall in the number of Oamaru patients scanned on the base hospital scanner in Dunedin following commissioning of the rural scanner. In 2008 and 2009, 538 scans were performed on Oamaru patients in Dunedin. This fell to 337 in 2010, but then rose steadily to 567 in 2011 and 655 in 2012.

Table 16 details the workload of the Oamaru scanner in its first years of operation. The mix of scans undertaken is very similar to that undertaken on the base hospital scanner in Dunedin.

Table 16: Scans performed on Oamaru scanner by scan type and year

	2010 (%)	2011(%)	2012 (%)
Head	290 (34.6)	211 (38.6)	287 (43.8)
Facial Bones	31 (3.7)	3 (0.5)	16 (2.4)
Chest	114 (13.6)	78 (14.3)	88 (13.4)
Abdomen	230 (27.4)	134 (24.5)	159 (24.3)
Chest/Abdo/Pelvis	40 (4.8)	29 (5.3)	53 (8.1)
Spine	43 (5.1)	20 (3.7)	16 (2.4)
Pelvis	6 (0.7)	6 (1.1)	4 (0.6)
Extremity	25 (3.0)	13 (2.4)	9 (1.4)
Colonography	60 (7.2)	52 (9.5)	23 (3.5)
Total	839	546	655

Discussion

This study has identified a considerable disparity in the utilisation of CT services between rural and urban communities in Otago. A local CT scanner significantly improved access to CT for rural patients in the Oamaru catchment by increasing scanning rates and reducing the waiting time for a scan. By contrast CT utilisation by rural communities without a local scanner had dropped even further behind those of the urban centre by the end of the study period.

The sharp rise and then levelling off in scanning rates for Oamaru when the scanner was commissioned there suggests the high rates seen in the first two years of the scanners operation were the result of pent up demand rather than long term over servicing. In later years scanning rates for Oamaru were similar to those of Dunedin.

The rural versus urban disparity in CT utilisation we identified is much larger than that identified in the Ontario study. (89) The response to installation of a local scanner was however similar in that both Oamaru and the Ontario rural community went on to have scanning rates similar to their nearby urban centre.

About half the scans for Oamaru patients are still being undertaken at the base hospital. This combined with the increase in the rural scanning rate has meant the installation of a scanner in Oamaru resulted in a relatively small reduction in workload for the Dunedin scanner. This is in part because of funding considerations and established referral patterns that have been slow to change. Some specialists still refer Oamaru patients, who could easily have their scan done locally, to the Dunedin scanner. An effort is being made to resolve these issues and it is likely that in future more than 50% of scans for Oamaru patients will be undertaken on the Oamaru scanner. A significant percentage of scans for rural patients will always need to be performed at the urban base hospital for clinical reasons; usually because the scan is part of the inpatient management of a condition that requires base hospital care. This rate is likely to vary depending on the clinical capabilities of the rural hospital. However, because of the issues outlined above this study does not throw light on what percentage of Oamaru patient scans still need to be undertaken at the base hospital for purely clinical reasons.

Rural CT scanners appear to be more common in other developed countries than they are in NZ. In a 2008 survey 88% of American “Critical Access Hospitals” had on site CT. (121, 122) “Critical Access Hospitals” are those with less than 25 beds and are more than 35 miles from a larger institution. (122) Therefore they are comparable to New Zealand rural hospitals. No rural New Zealand hospital with less than 25 beds had on site CT in 2008. The Royal Australasian College of Surgeons Division of Rural Surgery maintains a register of Australian surgeons practicing in remote locations. Twenty-three percent of the surgeons on this register have 24 hour, 7 day per week access to CT in their local hospital. (123) These hospitals are likely to be larger than Oamaru, which has no on site surgical facilities.

This study is limited to experience at a single rural CT site. Other rural hospitals with different local and regional health services and different geography may see different changes in scanning rates following the installation of a scanner.

There is a private CT scanner in Dunedin that accepts private referrals from across the region. Data for this scanner was not available and not included in the study. It is not possible to determine the impact the private scanner has on individual catchment rates although it is unlikely that rural patients would utilise this scanner more than Dunedin patients living nearby.

A number of patients may have travelled outside the Otago region for a CT scan and these scans have not been included. It is expected that these numbers would be very low.

This study does not address the important question of whether the differences in scanning rates we observed resulted in differences in health outcomes. The literature is limited and divided on this question. There is Scottish and Canadian research suggesting that patients in rural communities with a local scanner are more likely to receive treatment consistent with current best practice stroke guidelines than those living in communities without a local scanner. (124, 125) One small Irish study that suggests that the lower scanning rates for traumatic head injury in a rural community without access to local CT does not result in adverse patient outcomes. (126) There is a larger body of literature that suggests the greater use of complex imaging is not always associated with better patient outcomes. (41, 42, 127)

Whether lower utilisation of diagnostic imaging impacts on healthcare outcomes for rural patients remains unclear, as does the extent to which increasing local services can improve healthcare outcomes. These are important questions that warrant further research.

Conclusion

Local CT scanners are now a realistic option for many rural communities. A rural CT can overcome the rural versus urban disparity in utilisation rates. The improved access for rural patients does not appear to be associated with over servicing when compared to the nearby urban centre.

-End of published manuscript-

Addressing the evaluation framework

The major finding of this study was that after a rural CT service was established, CT utilisation rates for the Oamaru community approximated those of the region's urban communities. Over the same time, disparities persisted for the region's other rural communities that did not have local access to CT.

The findings of the studies in chapter 2 demonstrated inequities in access to CT for rural communities, and chapter 3 provides evidence that this was impacting on patient care, specifically with respect to adherence to evidence-based clinical guidelines. This result established an unmet health need in this community for this service, an indicator for the *appropriateness* of a rurally-based service.

The increased rural utilistion rates following the introduction of the Oamaru scanner in line with urban rates is an indicator of improved *equity*, a performance measure in the outcomes domain of Reeve's evaluation framework. Considering the impacts and costs on patients and their families, a reduction in the number of patients having to travel to the city for CT scans would be considered an indicator of improved patient wellbeing. However, this study did not demonstrate a reduction in the number of CT scans being undertaken on the urban scanner for this rural population. The reasons for this are considered in the discussion. The study did not address the outcome performance measures of morbidity and mortality, but the effect that higher utilisation rates might be having on these outcomes is considered in the discussion.

This paper also offers evidence of the *accessibility* and *efficiency* of the rural service. Once the service was established, Oamaru residents were able to access CT scannng without having to travel the 110km to Dunedin and their wait time for a CT scan fell dramatically. By both these indicators, the service improved the *accessibilty* of CT for this rural community. The service was provided in the rural town by the existing team of radiographers, suggesting it could be provided in a cost-effective manner. Importantly, this study found no evidence of over-servicing as a consequence of the local service. This is a positive indicator for the *appropriateness* and the *efficiency* of the service.

The SDHB installed a CT scanner at Dunstan Hospital in Clyde in 2013, and at Lakes Hospital in Queenstown in September 2019. The Dunstan decision was made after the collection of the data but prior to the publication of the papers in chapters 2 and 4. The Queenstown decision was made after publication. SDHB planners and managers were aware of the study results when they made these decisions and are likely to have been influenced by them. As of June 2019, only five NZ rural hospitals (out of a total of 26) have onsite CT. Three of these are in the SDHB region.

Chapter 5: Point-of-care testing in a rural hospital

Context statement

This study addresses the broad thesis research questions: *Does the service aid diagnostic decision making? Does the service have an impact on patient management? Is the service cost effective? Does the service improve patient outcomes?* This is achieved by addressing the specific research question: *What is the impact of point-of-care laboratory testing on diagnostic reasoning and patient management in a rural hospital without an onsite medical laboratory?*

Rural health is ‘different’ and is not simply the delivery of healthcare in another place. (128) It is neither practical nor desirable to provide the same level of specialist services in every community regardless of size and geography. Innovation is therefore crucial in rural health service delivery; the ability to develop pragmatic solutions that meet the health needs of rural communities in a safe and cost-effective manner. This includes being able to recognise and adopt the opportunities offered by evolving technologies. The studies in chapters 5 and 6 evaluate the introduction of point-of-care laboratory testing (POC testing), originally designed for use in urban intensive care units and emergency departments, in an isolated rural health service that previously had no local laboratory service. This takes the theme of rural diagnostic services a step further; using this technology in a different (rural) context raised questions around quality control and the impact on clinical practice that were not applicable to the CT service descibed in chapter 4.

The study uses a mixed methods design that is repeated in subsequent studies in the thesis. The participating rural doctors were asked to record their differential diagnosis and their intended patient disposition (discharge, admission to the local rural hospital, or transfer to the base hospital) prior to undertaking the test. They then recorded the same information after the test in light of the new information provided by the test results. The differences were used to assess the effect the test had on diagnostic certainty and admission, discharge, and transfer rates. This design is used again in the POCUS study in chapters 9 to 12. A brief cost minimisation analysis was undertaken by the hospital manager. A series of qualitative interviews was undertaken with local doctors to explore the impact of POC testing on clinical practice in more depth (chapter 6).

Blattner K, Nixon G, Dovey S, Jaye C, Wigglesworth J. Changes in clinical practice and patient disposition following the introduction of point-of-care testing in a rural hospital. Health Policy. 2010;96(1):7-12.

Introduction

The laboratory is now such an integral part of a modern hospital that it would be hard for clinicians working in an urban hospital to imagine providing acute medical care without access to urgent blood results. Yet this is the situation in many hospitals in rural and remote communities, even in developed countries such as New Zealand. (67)

The last decade has seen a rapid advance in point-of- care (POC) portable analytical laboratory systems. A wide range of laboratory tests can now be conducted rapidly, simply and reliably at the bedside. POC testing was initially developed for use in critical care units and emergency departments of secondary and tertiary care hospitals. It is now widely used in these settings where it is run in combination with a full on-site laboratory. (129) Much of the research on POC testing has also occurred in these large urban institutions where it has been shown to speed treatment decision-making and improve clinical outcomes. (130)

It is likely that the benefits of POC testing in rural acute settings, such as rural hospitals without an onsite laboratory, where the turn-around time for blood test results is often more than 24 h, will be even greater than in large hospital emergency departments where conventional laboratory turn-around time is usually less than 1 h. A 2001 Australian review concluded that rural and remote health practices in particular would benefit from the adoption of POC testing. (131)

Some rural hospitals in New Zealand have recognized this and have introduced POC testing. However, as yet there is no published New Zealand or international research investigating the impact of introducing POC testing to a rural hospital with no pre-existing on-site laboratory facilities.

In June 2008 a POC test analyser was installed in the small hospital in Rawene that serves the remote Hokianga region in New Zealand. This enabled clinicians to perform a small range of on-site tests (Table 17) for acutely unwell patients. During the study period, most POC tests were performed by doctors. Seven medical and 15 nursing staff received training from the manufacturer in the analyser's use. An ongoing quality control programme was established by the Northland District Health Board laboratory including procedure documentation, regular further training and certification, and software updates. A detailed Quality Assurance Programme Report is available from the authors.

Table 17: Point-of-care tests performed during the study

Type of test	Definition	Number performed
Chem 8	Sodium, potassium, chloride, glucose, creatinine, calcium, urea, haematocrit, haemoglobin	116
TnI	Troponin I	83
BNP	Brain natriuretic peptide	44
INR	International normalised ratio	11
CG8	Blood gas, electrolytes, haematocrit, haemoglobin	15

A qualitative study, reported elsewhere, (132) examined in-depth understanding of the effects of the introduction of POC testing on clinicians and the community. The present paper reports analyses of quantitative data collected to measure changes in clinical decisions (diagnostic certainty and patient management including decisions around admission, discharge and inter-hospital transfer) associated with POC test use. It also reports an analysis of the financial impact of introducing this technology into a remote rural hospital.

Background

Rawene Hospital is situated in the far north of New Zealand. The hospital is an integrated part of Hauora Hokianga Enterprises Trust which provides all local health services for the Hokianga region. It serves one of the most socio-economically deprived populations in New Zealand (Deprivation Index 10-most deprived decile (133)). Services are centred in the hospital in the small town of Rawene. The community is mainly Māori (70%) and the population of 6500 is dispersed over a wide geographic area (1521 km^2). Rawene itself is an hour's drive in addition to a 15-min ferry crossing from the farthest reaches of the Rawene Hospital catchment area. There is no public transport system in the Hokianga.
Rawene Hospital is the sole emergency service in the area, providing 24-h emergency and accident service for the Hokianga region. The hospital has 10 acute beds. Seven salaried general practitioners provide all local medical services. Their work includes acute and after-hours care at the hospital as well as standard general practice at Rawene Health Centre and nine peripheral clinics across the Hokianga. The nearest base hospital is in Whangarei, 2 h away by road. The nearest tertiary centre (providing specialist services such as interventional cardiology, neurosurgery, and vascular surgery) is in Auckland, a 4h journey by road.

There are about 750 acute admissions to Rawene Hospital annually: about 20% are transferred. Most go to Whangarei but some transfers are made directly to tertiary services in Auckland. Diagnostic services are limited. Plain X-rays are available only during normal working hours. There are no on-site laboratory services. Laboratory specimens are couriered to Whangarei each weekday morning. Urgent results return early the same evening by fax.

This provides for a turn-around time of 8–26 h on a weekday but up to 72 h at weekends and even longer on holiday weekends.

The range of clinical presentations in Rawene is similar to any acute admitting hospital in New Zealand although the Hokianga, like many other indigenous rural communities, has high rates of heart disease, diabetes and renal disease. It also has one of the highest rates of Acute Rheumatic Fever in the developed world. (134) It is well documented that at all levels of deprivation, New Zealand Māori experience greater morbidity and mortality than non-Māori. (135)

Methods

Study data were collected from 9 June to 30 November 2008, immediately after the POC test analyser was installed and clinicians trained in its use. All seven doctors working in Rawene Hospital agreed to participate in the study and collect data every time they used the analyser. Of the seven doctors, (three women and four men, average age 50 years) four are vocationally registered general practitioners and three are working towards full vocational registration. Two also hold postgraduate qualifications in rural hospital medicine. The doctors have worked in the Hokianga between 18 months and 30 years.

Each time doctors ordered a POC test for patients under their care, they completed a study form that collected data on test type(s), and the time, day and indication for the test. The data collection form was adapted from those used by Lyon and McLean. (136, 137) Before knowing the test result, doctors reported their differential diagnosis and the planned disposition of the patient, based on their clinical assessment alone. After the test result was available, they recorded the result, the differential diagnosis in light of the test (post-test differential diagnosis) and the actual patient disposition. Disposition was coded as “discharged home”, “admitted to the local hospital in Rawene” or “transferred to base hospital in Whangarei”.

The study data form also asked the doctor to indicate whether the test result had altered the patient’s treatment, categorizing this as “no change”, “some change” or “substantial change” in treatment. It was left to individual doctors to determine what constituted treatment change in each of these categories.

Anonymous completed data forms were collected by the lead investigator (KB) who was also one of the doctors involved in the study. Data were transferred onto a spreadsheet which was then imported into statistical software for analysis in the Department of General Practice at the Dunedin School of Medicine. The analytic strategy first described the distributions of each variable in the data collection and then used chi-square and paired t-tests to compare, pre- and post-test, the number and type of differential diagnoses, planned and actual patient dispositions, and changes in treatment plans.

Direct and indirect costs of POC testing were included in the financial analysis of costs and benefits. Direct costs included the initial purchase of the equipment, consumables, a quality program that included equipment calibration and credentialing of clinical staff, and staff training. Indirect costs were overheads estimated as 10% of total direct costs. All costs were exclusive of Goods and Services taxes.

Although data collection covered a 6-month period, costs were projected annually. The purchase cost of the equipment was allocated through the ‘Straight Line’ depreciation method. The life of the asset was assumed to be 5 years and therefore the annual cost for this analysis was 20% of the purchase price. Cost of the quality program was the price quoted by the Northland District Health Board, who provided the program. Consumable costs were based on the actual 6-month usage. Staff and training costs were based on measured medical and nursing time.

Tangible or quantitative estimates of benefits were estimates of the savings derived from changes in disposition of patients in the study. There were three categories of savings and costs: the cost of admission and patient care at Rawene Hospital, the cost of admission and patient care at Whangarei Hospital, and the cost of transfer between Hokianga and Whangarei Hospitals. A blunt averaging model was used to estimate these costs, based on the following assumptions: the average cost of care of a patient admitted to Rawene Hospital based on the per patient total patient ratio of the annual running cost of the hospital = $4000; the average cost of transfer between Hokianga and Whangarei Hospitals (sometimes by road and sometimes by helicopter) = $1900; the average cost of care of a patient admitted to Whangarei Hospital based on an average Diagnosis Related Group cost = $5000.

An analysis of intangible benefits has been reported separately (132) and includes: clinicians being able to appropriately assess and provide patient care without moving patients unnecessarily - thereby reducing stress and costs on patients and families; improved access to appropriate care for an isolated and high needs Māori community; improved job satisfaction for clinicians; improved communication and integration of patient care between hospitals.

This study received ethical approval from the Northern Regional Ethics Committee.

Results

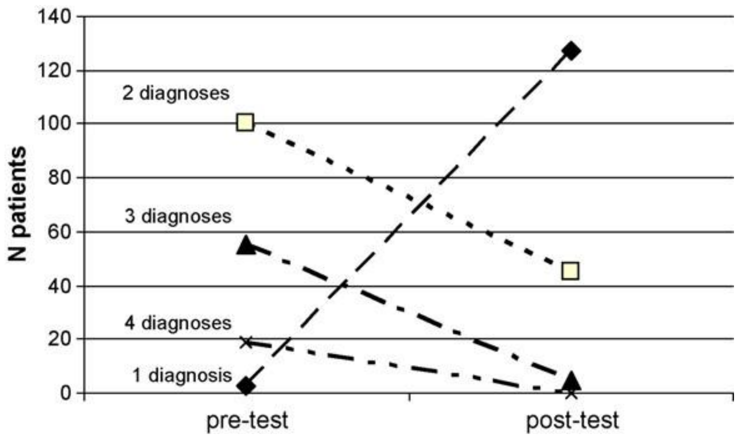
Over the 6-month study period POC testing was undertaken on 177 patients and 269 separate POC tests were performed (mean of 1.5 tests per patient). Data on disposition and changes in treatment were unavailable for 1 patient. There were 333 acute admissions to Rawene Hospital in the same time period. POC testing was used for more than half of all acute admissions (53.2%).

On average POC tests were used 1.5 times each weekend day and 0.8 times each weekday. Patients presenting on weekend days were more likely to have POC tests than patients presenting on weekdays ($p < 0.001$) but there was no significant difference between week- and weekend days in the number of tests per patient ($p = 0.688$) or in changed patient treatment or disposition patterns. Table 1 shows that the Chem8 battery of tests was used most often, followed by troponin.

Differential diagnosis

POC tests narrowed the differential diagnosis 93.8% of the time it was used, did not change the number of differential diagnoses in 5.1% of cases, and broadened the differential diagnosis in 2 cases (1.1%). In two thirds of cases (119; 67.2%), one potential diagnosis was ruled out, in 25% of cases 2 potential diagnoses were ruled out and in 2 cases (1.1%), 3 potential diagnoses were ruled out. On average, there were 2.5 diagnoses considered pre-test, and 1.3 diagnoses post-test (paired t-tests $p < 0.001$). POC tests enabled a firm diagnosis (differential diagnosis of 1) in 72% of presentations where it was used. Changes in the number of differential diagnoses considered pre- and post-POC test are shown in Figure 6.

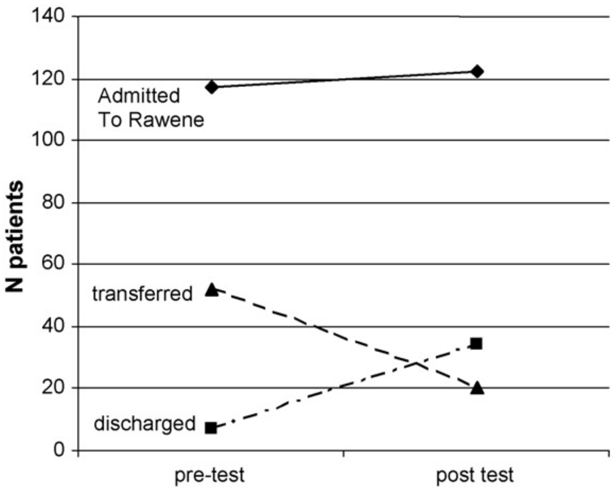
Figure 6: Changes in number of differential diagnoses pre- and post- POC test



Disposition

Figure 7 shows changes in patient disposition pre- and post-POC testing. Without POC tests, doctors would have decided to admit 117 patients (66.5%) to Rawene hospital, transfer 52 (29.5%) to Whangarei or Auckland hospitals, and discharge 7 (4.0%). Informed by POC tests, admissions to Rawene hospital were relatively stable (122 (69.3%) but the number of intended transfers to base hospital reduced by 62% (52 pre-test and 20 post-test) and the number of discharges increased by 480% (7 pre-test and 34 post-test). Overall, POC testing changed disposition for 43% of the patients for whom it was performed ($p < 0.001$), on both weekdays and at the weekend. Frequently this meant continuing to manage locally patients who would have been transferred to base hospital if POC test results were unavailable (77%, 40 out of 52 patients). It also meant discharging patients who would previously have been admitted (22%, 26 out of 117). However some patients had their level of care escalated as a result of POC test results: 8 patients who were originally intended for local management were instead transferred to base hospital.

Figure 7: Changes in patient disposition pre- and post-POC test



Change in treatment

Doctors reported that POC testing resulted in a substantial change in treatment in 75.1% of cases, some change in 22.0% of cases and no change in 2.8% of cases. Examples of substantial changes in treatment included adding anti-platelet agents and heparin in a patient with an acute coronary syndrome, arranging urgent transfer in a patient with previously unsuspected acute renal failure, and correcting hypokalaemia in a patient with a cardiac arrhythmia. Examples of some changes in treatment included altering intravenous fluid and electrolyte replacement and altering warfarin dosing.

Financial analysis

Table 16 shows the financial costs and savings of POC testing, and attributes them to either the Hokianga Health Enterprises Trust, working within its primary care budget, or the Northland District Health Board which is financially responsible for both the Whangarei Hospital operations and primary care funding allocated to the Hokianga.

There was an overall benefit to the public health care system, as a whole, estimated at $362,138 annually. This comprised a net cost to the Hokianga Health Enterprise Trust of $90,222 and a net benefit to the District Health Board of $452,360.

Table 18: Annualised financial costs and benefits of POC testing at Rawene hospital[a]

	Savings (+) or cost (−) to Hokianga Health Enterprise Trust ($)	Savings (+) or cost (−) to Northland District Health Board ($)
Annual operational savings (+) or cost (−)		
Depreciation cost of analyzer	−2,872	0
Consumables	−33,535	0
Quality programme	−1,200	0
Staff training time	−2,300	0
Staff operational time	−5,750	0
Overheads	−4,566	0
Total operational savings (+) or cost (−) annual	−$50,222	$0
6-Month patient care-related savings (+) or cost (−)		
Initially for transfer, changed to admit (38)	−152,000	262,200
Initially transfer changed to discharge (2)	0	13,800
Initially for transfer, no change (12)	0	0
Initially admit changed to discharge (26)	104,000	0
Initially admit changed to transfer (8)	32,000	−55,200
Initially for admission, no change (81)	0	0
Initially for discharge, changed to admit (1)	−4,000	0
Initially for discharge, no change (6)	0	0
Laboratory tests (269)	0	5,380
6-Month total patient care-related savings (+) or cost (−)	−$20,000	$226,180
Annualised patient care-related savings (+) or cost (−)	−$40,000	$452,360
Total financial benefit (+) or cost (−) annualised	−$90,222	$452,360
Net financial benefit annualised	$362,138	

a Although collected over a 6-month period the costs and benefits have been annualised and are in $NZ

Discussion

Principal findings

POC testing into Rawene hospital improved doctors' diagnostic precision, and significantly altered the disposition of patients. Not surprisingly POC testing was used more frequently at weekends when the turn-around time was previously the longest (72 h). The tests that examined renal function, electrolytes and cardiac markers were used most often. This was expected considering the high rates of diabetes, renal and heart disease in this community and the often time-critical nature of these investigations.

POC testing benefited patients in that they were more likely to receive a firm diagnosis and consequent appropriate changes to the treatment they received. Patient disposition was altered for almost half of the patients and doctors were given the means and confidence to continue managing more patients locally, resulting in a significant reduction in inter-hospital transfers. In addition more patients could be discharged home after initial assessment. The small number of patients (5%) whose disposition was changed to “transfer” as a result of their POC test will be benefited from having received the specialist care they needed sooner.

The effect of POC testing on reducing the need for transfer takes on additional meaning for this community from a cultural perspective. For local Māori other social and cultural priorities can take precedence over health matters. Local Kaumatua (elderly), especially, have an intrinsic connection with their whanau (family), whenua (land), their living environment, their sustenance, and are concerned with their ‘kaitiaki’ responsibilities, which are left bereft in their absence. While away from home they suffer emotionally as a result. Their spirit is diminished and healing takes longer. Thus frequently the sicker they are the less likely they are to agree to transfer to a distant base hospital. It is not unusual for a patient to be so concerned about dying far from their traditional home that they will decline transfer despite compelling medical reasons.

The information provided by POC testing can influence access to specialist investigations and treatment. In a community such as the Hokianga, the early recognition of cardiac problems is particularly important: despite Māori having higher rates of cardiac disease than non-Māori

New Zealanders, they also have lower rates of intervention (CABG and PTCA). (138) The prompt diagnosis and referral of Māori patients with an acute coronary syndrome is the first step in correcting this disparity. Immediate access to testing for cardiac troponins means that rural hospital patients with acute coronary syndromes can be identified earlier, treated with more aggressive antiplatelet and anticoagulant therapies, and transferred for more timely intervention to the tertiary centre for coronary interventions. Current guidelines call for all patients presenting with a suspected acute coronary syndrome to have a troponin result available within 1 h and preferably within 30 min. (139)

Strengths and weaknesses

The doctors were asked to hypothesise on their likely decisions before doing the POC test, when they knew that the test result might alter these decisions. The actual reduction in transfers may be less than the 62% recorded. When completing the study form the doctor may have based this intention on best medical practice. The actual decision to transfer is a much more complex one that includes the wishes of the patient and their family and the resources of the health care system. Rural clinicians know that when faced with these other issues many patients may not actually be transferred (or vice versa). The change in intention in some situations will reflect an actual change in management as a result of POC testing; in other cases it will mean the doctor is no longer compromising what they consider best medical practice by continuing to manage the patient themselves. While these both are positive outcomes only the former will reduce health care costs. Some support for a real reduction in transfer rates is found in Rawene hospital transfer records. In the year prior to the implementation of POC testing 19% (118 out of 623) of admissions to Rawene hospital were transferred. (140) In the first 6 months of POC testing this fell to 14% (50 out of 354) of admissions. This is not a statistically significant difference ($P = 0.0524$ chi-square test) but if all this reduction was attributed to POC testing it would amount to a 52% reduction in transfers among admissions who had POC testing undertaken.

Some of the doctors participating in the study had reservations about the introduction of POC testing to Rawene Hospital and some had a preference for more POC laboratory testing. Both views may have affected their responses initially, but probably resolved during the study. We were unable to take this into account in the analysis.

Many other small rural hospitals in New Zealand also lack on site laboratory services. (67) Translation of our findings to other rural areas (i.e., the impact of POC testing) needs to take into account the remoteness of the Hokianga, the high deprivation status and high morbidity of the catchment population, and the restricted availability of diagnostic services prior to the introduction of POC testing.

Policy implications

Policy decisions about the use of POC testing in the setting of acute care in rural hospitals will depend on the perspective taken. If the decision is made on clinical grounds, the evidence for its facilitating better clinical decision-making is compelling and would support the adoption of POC tests. If the decision is made on a population basis, there is a logical argument in support of POC test use on the grounds that better clinical decisions made for a socioeconomically deprived population will reduce health inequalities between this population and less deprived ones. The resulting reduction in health inequities will be multiplicative when new technology such as POC testing is introduced to a community such as the Hokianga that is disadvantaged, predominantly Māori and remote from a major hospital. If the decision is made on financial grounds, it is more complex. Hokianga Health

Enterprises Trust might well decide that it cannot afford to continue to provide resources for this activity given the negative impact on its budget. On the other hand, it appears to generate a savings for the District Health Board, which is responsible for all health services within the district, so a policy decision at that level would probably be essential to support its continued use.

Conclusion

In an increasingly specialized, high tech and financially stretched healthcare system the value of small rural hospitals may be questioned for lack of collective team expertise and resources, and therefore their ability to provide an appropriate standard of care. An apparently different admission threshold may also exist because rural hospital patients are admitted for observation, serial clinical assessment being used as an alternative to the investigations available in urban hospitals. Rural hospitals provide the bulk of the acute medical care for their communities. This study has shown that rural hospital generalists can readily adopt a new technology; using it to improve patient care and reduce hospital admissions and inter-hospital transfers, with resultant savings to the healthcare system.

-End of published manuscript-

Addressing the evaluation framework

The indicators used to evaluate rural POC testing in the study addressed many of the performance measures in the *structure* and *process domains* of the Reeve evalation framework.

Accessibility: Unlike the intermittent courier service to the distant medical laboratory, POC testing was locally available 24 hours a day.

Effectiveness: The study demonstrated that the POC testing was effective in increasing diagnostic certainty; POC testing reduced the the size of the differental diagnosis in more than 90% of cases, and resulted in diagnostic certainty in more than 70% of cases.

Efficiency: A cost-benefit analysis demonstrated tangible savings to the health service in the form of reduced hospital admissions and inter-hospital transfers. These savings greatly outweighed the costs of running the service.

This is the first study in the thesis to examine the effect of a rurally-based diagnostic service on patient discharge and transfer. The decision to transfer a patient to a distant institution has implications for patients and their families that go beyond the level of clinical care they receive. These are some of the most resource-intensive decisions rural doctors routinely make. Even a relatively small overall reduction in inter-hospital transfers will result in significant savings for individual patients and the healthcare system. Undertaking an indepth economic analysis (e.g. cost utility analysis), that examined the costs and benefits of rural POC testing in a comprehensive manner would have been a complicated undertaking that was beyond the scope of this small study. This is becasuse the differences in patient management outcomes between a send away lab test and and an immediately POC test would be difficult to quantify. While change in disposition is only one outcome, in the rural context it is an outcome that is a major patient and health system outcome that can be measured.

The equally important intangible costs of transfer that are born by patients and their families, especially in a remote, predominantly Māori community like the Hokianga, are examined more closely in chapter 6.

Future directions

As part of the continued evolution of point-of-care laboratory technology, haematology analysers capable of cell counts are now available. In 2016, Hokianga Health added a haematology analyser to its range of POC tests and undertook an evaluation. This study has not been included in the body of this thesis but was undertaken by the same research team using the same methodology as the study described in this chapter. The results were published in Rural and Remote Health in 2019. (141) Similar conclusions were reached, namely that the POC haematology analyser in the Hokianga reduced inter-hospital transfers and resulted in overall savings to the health service; had a positive impact on clinical practice by improving diagnostic certainty and improving communication with referral centres; and had added relevance from a cultural perspective by reducing the need to transfer Māori patients away from whenua and whānau.

There has been a strong uptake of POC testing across rural NZ, both in rural hospitals and isolated rural primary care. It is likely that the dissemination of these study results have played a role in the spread of this technology in rural NZ. In May 2019, we published a survey of POC troponin use in NZ rural hospitals. (142) Twenty-two of the 23 hospitals that responded to the survey had access to onsite troponin (Tn) testing. Of these, 17 used POC Tn assays. A rural rapid chest pain assessment pathway has been developed specifically for use with POC Tn assays; *Miller R, Nixon G. The assessment of acute chest pain in New Zealand rural hospitals utilising point-of-care troponin.* (143)

Chapter 6: Point-of-care testing, thematic analysis of interviews

Context Statement

In the second part of this mixed methods study, a qualitative approach is applied to the same set of aims and research questions as chapter 5. Many of the benefits demonstrated in the quantitative evaluation of the POC testing service (chapter 5) were explored in greater depth and reinforced by the qualitative findings generated by in-depth interviews with local healthcare providers.

The ultimate aim of improved outcomes for rural patients will only be achieved if the lessons learnt in establishing the diagnostic services are successfully passed on to other rural healthcare providers. Many of the important lessons that relate to setting up and resourcing the rural service and the intangible benefits (to clinical practice, patient wellbeing, cultural appropriateness and job satisfaction) were captured in the qualitative findings. Much of this information would have been lost had the quantitative findings been reported in isolation.

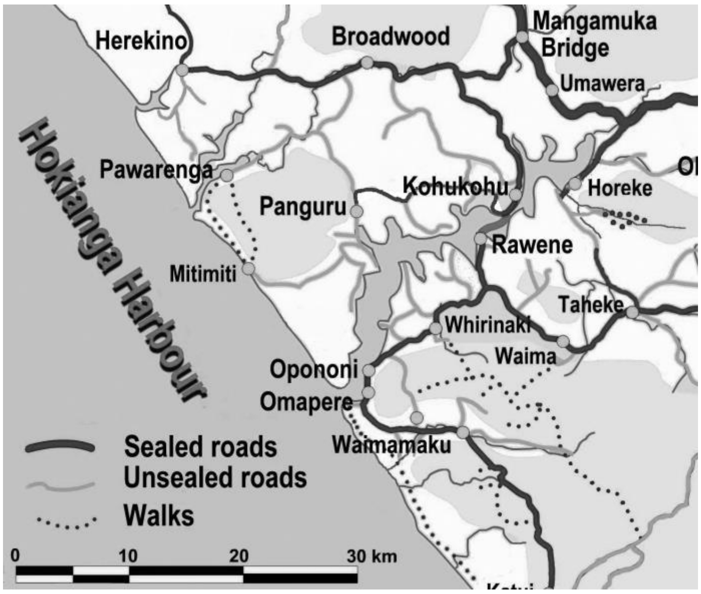
Blatter K, Nixon G, Jaye C, Dovey S. Introducing point-of-care testing into a rural hospital setting: thematic analysis of interviews with providers. J Primary Health Care. 2010;2(1).

Introduction

The concept of primary health care described in the Declaration of Alma-Ata (144) encompasses the activity of health care providers who are the first point of health system contact for patients and who are based in a community, rather than in an institution. (145) In rural New Zealand, as in rural areas throughout the world, primary health care must address the myriad health care needs of geographically-isolated communities, crossing the primary–secondary interface. Australian research has shown that the proportion of general practitioners providing complex services increases with increasing rurality or remoteness. (146) Rawene Hospital is an integrated part of Hauora Hokianga Enterprise Trust Primary Health Organisation (PHO). It serves one of the most socioeconomically deprived populations in New Zealand (Deprivation Index 10 - most deprived decile). (147) The community is mainly Māori (70%) and the population of 6500 is spread over an area of 1521 km^2. The Hokianga road network is well behind the standard seen elsewhere in Northland and New Zealand and many roads in the area remain unsealed, as shown in Figure 8. (148) The harbour, which was well suited as a medium for water transport in earlier years, has become a physical barrier for access between north and south Hokianga, with a vehicle ferry maintaining the cross-harbour link.

Rawene Hospital is the sole emergency service in the area, providing 24-hour emergency and accident service for the Hokianga region. The hospital has 10 acute beds. Seven salaried general practitioners provide all local medical services at Rawene and also visit nine peripheral clinics located across the Hokianga. In contrast to GPs working in urban settings, both acute and after-hours care are part of their work which covers the whole scope of primary, secondary and emergency care. Diagnostic services are limited, for example plain x-rays are only available during normal working hours. The nearest base hospital is in Whangarei, two hours away by road. Rawene itself is an hour's drive in addition to a 15-minute ferry crossing from the farthest reaches of the Rawene Hospital catchment area. There is no public transport system in the Hokianga. There are about 750 acute admissions to Rawene Hospital annually: about 20% are transferred, the majority to Whangarei with some transfers directly to tertiary services in Auckland.

Figure 8: Map of Hokianga



There is considerable variation between different rural communities around New Zealand in access to laboratory services. (67) In Rawene there are no on-site laboratory services. Laboratory specimens are couriered to Whangarei on working days only, so the turn-around time for a test result is up to three days.

Prior to 2008, clinicians had access to limited point-of-care (POC) tests on site, similar to that of many general practices: urinary dipstick, urinary β HCG, blood glucose, INR and qualitative troponin.

Blood tests have become essential to acute clinical medicine and consistently good patient care is impossible without them. Doctors in rural hospitals in New Zealand are often faced with complex acute medical problems without immediate or even intermediate access to basic laboratory tests to help guide management, including decisions about patient transfer to specialist care services. POC analytical systems enable a range of laboratory tests to be done quickly with portable equipment. The key object of POC testing is to generate a result quickly so that appropriate management decisions can be made leading to an improved clinical or economic outcome. POC testing is now widely available, but still used mainly in settings with a full on-site laboratory. (129, 149) There is surprisingly little research into the role of POC testing in small rural hospitals. It is likely that the benefits in rural settings, where the turn-around time for conventional laboratory tests is extended, will be far greater than in hospital settings where results can be more immediately available. Some rural hospitals in New Zealand are already using POC testing, but no research has yet investigated the impact of introducing this service to a rural hospital with no pre-existing on-site laboratory facilities.

In 2008 a POC test analyser was installed at Rawene Hospital to enable clinicians to perform on-site tests in acutely unwell patients and thereby to improve diagnostic self-sufficiency and patient care. The tests this system performs are shown in Table 19. A Rural Innovation

Fund grant was used for a wider project about the introduction of POC testing at Rawene, including a quantitative study designed to measure changes in diagnostic certainty, patient disposition and costs. This is to be reported elsewhere. (80) The qualitative study reported here aimed to provide in-depth understanding of the effects of introducing POC testing to a small rural hospital from the viewpoint of the clinicians involved.

Table 19: POC tests, Rawene 2008

CHEM8	sodium, potassium, chloride, glucose, creatinine, ionised calcium, urea, haematocrit, haemoglobin
CG8	Blood gas, sodium, potassium, glucose, haematocrit, haemoglobin
TnI	Troponin i
BnP	B-natriuretic peptide
InR	international normalised ratio

Methods

Participants comprised all of the seven doctors, three lead nursing staff, one manager, and two community health workers employed by the Hokianga Health Enterprise Trust and based at Rawene Hospital. While it was originally envisioned that interviews with all the doctors would provide sufficient data, this decision was reviewed to include nursing, community and management staff in order to provide broader perspectives on the impact of POC testing at Rawene hospital.

The length of respondents' employment at Rawene Hospital ranged from 18 months at the time of the interviews to 30 years. Written informed consent was obtained from all participants.

Table 20: Interview schedule

- What was the procedure prior to having POC testing?
- What do you do now?
- How has the introduction of POC testing affected your practice?
- Have you had to learn or relearn new things?
  - How did you find this?
- How have you found the technical aspects of doing POC tests?
- Has finding time to do the tests been a problem?
- What positive impacts has POC testing had on patient care?
- What negative impacts has POC testing had on patient care?
- Has POC testing altered diagnostic certainty?
- Has POC testing changed patient management, including treatment or transfer/discharge/admission decisions?
- in which kinds of cases have you found POC testing to be most helpful?
- What are the most useful tests and least useful tests?
  - Why?
- At which time (regular or after-hours) have you found POC testing most useful?
- Has POC testing had any impact on your job satisfaction?
- do you think performing the tests should be a medical or nursing role?
- What do you think is needed for a small hospital to set up and sustain this service?

GN and CJ interviewed all but one participant at Rawene Hospital over a two-day period early in 2009. One person not present at that time was interviewed by GN later. Most interviews were completed within 30–45 minutes.

The interview schedule (Table 20) included questions about the ways POC testing affected practice and patient care and about setting up and maintaining the POC test service. The interviews were semi-structured as the interviewers asked for clarification and followed participants’ responses. Interviews were digitally recorded and transcribed prior to analysis.

Transcriptions were entered in the computer-assisted qualitative data analysis software package ATLAS.ti and analysed in accordance with the general inductive approach described by Thomas. (150) Specifically, the interview schedule offered a working template for coding the data in a way that was consistent with the objectives of the study, while ATLAS' memo facility was used for more engaged interpretation to gain insights from the data. The result was a thematic analysis which also incorporated unanticipated and emergent findings.

The Northern Regional Ethics Committee reviewed and approved the study protocol.

Findings

The findings are presented in three primary themes

1. <u>Impact on clinical decision-making and clinician confidence</u>

Despite some initial scepticism, respondents found the availability of POC testing to be reassuring, and its use increased diagnostic certainty and improved their confidence in their clinical decision-making. Respondents reported relief from the negative impact of a lack of diagnostic certainty, and concern they had not previously offered the best possible care at times when they risked missing important patient problems.

> *A lot of what we admit here and what we… see here is acute exacerbations on top of chronic disease so… having those tests… made you feel much more confident in managing them here or transferring them, or discussing them with a consultant. It really should be part of the routine management when they present acutely and I guess we hadn't been doing that before.* (Doctor)

The capacity for POC testing in acute presentations sometimes resulted in unexpected and sometimes life- and organ-saving consequences. 'Things' were less likely to be missed, for example:

> *… young woman… came in one weekend just looking a bit sick and nothing very much except… she had quite a nasty external ear infection… She… mentioned after a few hours that she hadn't peed for a while and we… did some point-of-care testing and showed that she was in acute renal failure … her creatinine was up around a thousand. That was in the beginning, the very start when we got the machine. So the first thing we did was went back and rechecked the whole thing to make sure we had done it properly, but there it was over a thousand… she got to Whangarei 24 hours before she would have otherwise, more than 24 hours probably. (Doctor)*

All respondents gave examples of being able to manage conditions at Rawene Hospital that would previously have required transfer to Whangarei. Examples included chronic respiratory disorders and renal disease. Some respondents commented that, prior to POC testing, the 'crunch point' was Thursday night when a decision would have to be made either to keep the patient over the weekend or to transfer.

> *…You are not trying to fly by the seat of your pants for several days at a time watching somebody who may be getting worse, may be getting better, maybe not, and you don't know… (Doctor)*

Being able to do these tests at Rawene Hospital gave clinicians the confidence to manage patients who would otherwise have been transferred, just to be on the safe side.

> *… I had a fairly low threshold there for transferring. If I was going to sit and worry about someone through the night I probably would have transferred them, whereas others wouldn't have done, but certainly it has helped me keep people here. I am more comfortable doing that. (Doctor)*

POC testing has enabled transfer decisions to be made earlier than they otherwise would have been and has often meant that treatment can begin immediately, e.g. while waiting for a helicopter to arrive. Having POC test results also facilitated the transfer process to Whangarei and Auckland hospitals, sometimes resulting in a decision to transfer directly to Auckland rather than routing the patient through Whangarei base hospital. 'Knowing the numbers' when talking to admitting specialists at the receiving hospital after doing POC testing streamlines the process for patients when they arrive.

> *If you have got a… test to go with them… that gives you a more definite reason to transfer someone… So you already know that they are in acute renal failure and that their potassium is 'up the wok' and they need to be seen by the renal team so you can liaise with the renal physician rather than a medical registrar. So that they are already a little bit in the system by the time they get to Whangarei it is already one step ahead, rather than join the queue at the end of the ED department. (Doctor)*

Clinicians also expressed simply feeling less worried.

> *[Interviewer: Do you ever think you worry less about some patients because of it?]*

Oh yes, yes. It just gives you that peace of mind. (Doctor)

2. <u>Impact on the ability to provide health services to a disadvantaged and remote community</u>

POC testing reduced the need for inter-hospital transfer and increased the discharge rate, while hospital admissions were unchanged. (80) Most respondents mentioned the benefits of this for patients and their families who find being transferred to a distant urban hospital difficult and disorientating. Transferred elderly Māori patients, particularly, may become increasingly disheartened as they have to tell their story repeatedly to unfamiliar clinicians.

They don't have to tell their story a hundred times… it is just that non-familiarity with the whole place, new faces, inevitably always a new house surgeon, registrar and consultant if they even see the consultant. It is at least, three or four doctors they are going to see… By the time they get [there] they almost feel challenged that they are even sick and they often just clam up and say nothing or they will say there is nothing wrong with them because they want to just come back home. (Doctor)

Several participants reported that some elderly Māori patients simply refuse to transfer because they are worried that they will die away from home, which causes spiritual difficulties for their whanau and for themselves.

If they [elderly Māori] have got to go to Whangarei, it is probably one of the last options because the scary thing is, if they are sick, they go and they pass away in *transition or pass away there or they have got to be transferred somewhere else. People want to pass away back home in their own building… Take them to a new environment and they are lost and they become spiritually weaker. (Community health worker)*

3. <u>Challenges associated with POC testing</u>

Increased workload

While respondents were overwhelmingly positive about the impact of POC tests on clinical practice, it had also created challenges. One participant reported that the ward was busier because they were managing patients who would have previously been transferred and who now required more care as a consequence.

…our ability to manage more and more people here increases workload… Anything new that you can do just changes the boundaries in what we do… We do very long weekends when we are covering a ward that can have some quite sick people plus we are doing outpatients and A&Es and things at the same time. So it is a bit of a challenge that, and I think it is a creeping extension of the role that will go on. (Doctor)

Another suggested that although fewer patients were transferred, this was balanced by the numbers of patients who were discharged home earlier because POC test results gave clinicians the confidence to make this decision.

Higher standards of practice

POC testing has extended clinicians' management roles and skill base. 'Flying by the seat of the pants' prior to the acquisition of the i-STAT was contrasted with the need to respond appropriately to POC test results which often required more competencies of clinicians. This was sometimes set against the context of already challenging scopes of practice in rural hospital practice.

Continuing Professional Education (CPE)

Several respondents mentioned that refresher training had been organised on interpreting the results of tests such as B-type natriuretic peptide (BNP) and arterial blood gases. Arterial blood gases were cited as the least used POC test although there was agreement that it was a very useful test. Respondents pointed out that this test's underuse was partly because most doctors would not have done this procedure for many years, but also because of the up-skilling required to interpret the result.

> *Having the ability to do the test means that you then need to go on a step further in management than I would have done previously and that's probably a good thing in the long run but it is a challenge for the GPs who are using it... (Doctor)*

The confidence that CPE can make on clinicians' use of tests is illustrated in the following quotation regarding BNP test:

…[those of] us who are using it [BNP] are the ones who have had some more formal recent… cardiology teaching because it [BNP] is a new thing since most of us graduated. (Doctor)

Time-consuming

Several respondents commented that doing POC testing could be time-consuming, particularly in an emergency situation.

Time consuming. Not so bad during the day when there are a lot of people around but in the middle of the night when it is just me and the nurse and a really sick person…

Over-testing

There was concern that over-testing could become a problem. It was suggested that clinicians needed to be clear about why they were doing or ordering a particular test, should not go on general 'fishing expeditions', and should avoid testing that would not make a difference clinically.

…You have got the younger doctors, especially the trainees who come in and… do tests on everyone… They just don't function without the blood tests whereas some of the experienced doctors here have learnt to function without them and there is something good about that as well. (Doctor)

Discussion

Providing acute care for a remote, economically deprived community with limited access to diagnostic investigations can be difficult. Faced with uncertainty, clinicians worry that the care they provide is substandard and their patients suffer. Our findings suggest that POC testing can help rural clinicians feel more certain about their diagnoses and make better patient management decisions. Patients receive more timely and appropriate care. For some patients this means earlier transfer. Clinicians also gain the confidence to continue to manage locally other patients they would previously have transferred. This may be particularly beneficial to many patients who find admission to a distant hospital difficult for themselves and their families.

At the same time, POC testing demands higher levels of clinical competence. Clinicians have to learn new skills so they can continue providing care for patients with more complex problems. This can challenge already stretched rural doctors, caught between wanting to practise a higher standard of medicine and managing a constantly increasing associated workload. These findings support previous research from Australia showing that rural clinicians are often faced with complex acute medical problems with no access to basic laboratory tests (146) and show that in this New Zealand rural setting POC testing had important benefits.

All doctors and a selection of others working at Rawene Hospital participated in this study, so a wide range of perspectives is represented. We report in the study the important effects of the introduction of POC testing that simply could not be adequately captured using other than qualitative research methods. These results add a depth of understanding about the impact of introducing POC testing that would be missed if we relied on our quantitative results alone.

Whereas in cities the general practice scope may have shrunk, in rural areas it remains comprehensive and keeping up-to-date across this entire scope is hard work, intellectually challenging, but also very professionally rewarding. This study is important for clinicians because it shows that, with access to diagnostic tests, rural clinicians have better diagnostic certainty and are likely to find more satisfaction in their work. This could have downstream positive effects on recruitment of clinicians into rural areas.

However, the study is geographically specific. Translation of these findings to other parts of the country needs to take into account the remoteness of the Hokianga, the high deprivation status and high morbidity of the catchment population, and the restricted availability of diagnostic services.

Some of the difficulty for Rawene Hospital in securing access to timely laboratory testing has been its model of funding: it is a non-government organisation (NGO) and an integrated PHO providing both primary and intermediate/ secondary care services. Most acute hospital and emergency department services in New Zealand are provided by District Health Board (DHB) managed secondary care services. It therefore does not fit neatly into the dominant New Zealand model of health care funding, which can act as a barrier to securing funding for secondary care. A recent Australian review of rural health service provision cautioned against underestimating the importance of macro-scale health policies and funding paradigms that support sustainable integrated local solutions for rural and remote communities. (151)

The study also has implications for rural communities. Since the release of *The Primary Health Care Strategy* in 2001 (152) the emphasis in primary care has been on public health services, with focus and funding prioritised for health promotion and illness prevention in the absence of illness expression. In rural areas the primary–secondary interface is blurred. All New Zealanders still need access to acute and urgent health services. Lack of timely access to diagnostics, even basic laboratory services, is currently a barrier to meeting the urgent health care needs of some rural communities and a reason for continued inequalities in health status and outcomes.

We conclude that POC testing aids the provision of higher quality care to our remote rural communities and therefore contributes to a reduction in inequalities in health services and outcomes. This is particularly important in view of the well-documented health disparities between Māori and non-Māori. (153)

Initial emergency and acute care in the Hokianga, as in many other rural areas, is provided by the rural hospital staffed by generalist doctors, and not an emergency department. Unlike their urban specialist colleagues, these doctors, as generalists, do not have access to a full range of investigations on- or off-site. This situation can be and should be partly ameliorated in the 21st century by improving access to clinical supports such as POC tests. Other research into the availability of laboratory services in New Zealand rural hospitals (67) showed that bigger hospitals were more likely to have both an on-site laboratory and near patient testing, suggesting that decisions about testing facilities are determined more by hospital size and budget than by clinical need and potential health and social gains from reducing base hospital admissions and travel. Such decisions accentuate inequalities for some of the most deprived New Zealand communities.

This research provides good grounds for concluding that New Zealand rural clinicians providing acute care, regardless of the size or funding model of their hospital, should have easy and uniform access to basic laboratory tests.

-End of published manuscript-

Addressing the evaluation framework

In their interviews, participants emphasised the significant health disadvantage faced by this community due to geographic isolation and high levels of socioeconomic deprivation, and the role of POC testing in reducing this disadvantage by improving access to laboratory tests. *Equity* was identified as a particularly important outcome. The *appropriateness, effectivness* and improved patient *wellbeing* were also hightlighted in the thematic analysis. The ability of POC testing to reduce unnecessary inter-hospital transfers was seen as a significant benefit in terms of improved patient *wellbeing. The participants noted the tangible and intangible costs* to patients, particularly elderly patients, when they are transferred to a distant hospital. These costs include removing them from the support of, and obligations to, their whānau and community, and exposing them to services that are less *culturally appropriate* than their local service. The participants also expanded on the finding in chapter 5 that POC testing improved diagnostic certainty, by suggesting this resulted in reduced clinical anxiety and improved job satisfaction. They also made the interesting observation that the additional information provided by POC testing significantly improved communication with base hospital doctors when referring patients or seeking advice. The POC testing results meant it was easier to ‘speak the same language’ as the specialists they were consulting.

Chapter 7: Rural cardiac exercise tolerance test service

Context statement

Disparities in access to cardiac exercise tolerance testing (ETT) may have wider implications for health equity. ETT in NZ is often a first step in accessing definitive investigations and treatment for ischaemic heart disease (angiography and PCI/percutaneous coronary intervention). Inequities in access to (ETT) could result in inequities in access to these important and costly interventions.

This study addressed the following thesis research questions: *What is the extent of existing rural vs. urban disparities in access to this service? Does establishing a rural service address access inequities? Does the service meet recognised quality standards? Is it safe? Does the service have an impact on patient management? Is the service cost effective?* This was achieved by addressing the specific question: *'Is ETT delivered in a rural area by local doctors and nurses safe and cost effective?'*

This study is similar to the CT study (chapter 2) in that it starts by attempting to quantify the extent of rural-urban disparities in access to the service, using utilisation as the indicator. Limited data on ETT utilisation was available for the smaller northern arm of this study, allowing conclusions to be drawn on the extent of pre-existing urban-rural disparities in access to ETT. Our inability to obtain data on ETT utilisation in the southern arm of the study is considered later in the chapter.

This study adds a new element to the studies in this thesis by introducing into rural areas a diagnostic test that is reliant on a skill set that usually sits with urban specialists. (ETTs are normally reported by cardiologists in NZ). Quality therefore becomes an important indicator of the *appropriateness* of the service; i.e *Is the service safe?* Quality was assessed by undertaking an audit of the local ETT reports, using parallel cardiologist reporting as the gold standard.

The capital costs, low volumes and need for skilled staff immediately raise concerns with health managers and policymakers about the viability of a rural ETT service. Efficiency was therefore given priority as a performance measure, as indicated by the cost effectiveness of the service.

Blatter K, Nixon G, Horgan C, Coutts J, Rogers M, Wong B, et al. Evaluation of a rural primary-referred cardiac exercise tolerance test service. NZ Med J. 2014;127(1406).

Introduction

Cardiac exercise tolerance test (ETT) is often the first step when investigating a patient with suspected ischaemic heart disease (IHD) or risk stratifying a patient with known IHD. The results of ETT often determine whether or not a patient proceeds to more complex cardiology investigations and treatment.

In New Zealand, public ETT services are generally provided in urban and provincial hospitals with specialist oversight. Few rural hospitals (only five in New Zealand at the time of this study, including the two in this study), offer ETT services.

There is little information on the impact of distance on the utilisation of urban based secondary services in NZ. This is in contrast to primary care where inequalities are acknowledged and there is both research and policy aimed at improving access for rural communities. (20)

Published evidence (both NZ and international) suggests rural patients have inferior access to cardiovascular diagnostic investigations including ETT compared with urban patients, and have poorer outcomes as a result. (70, 154-160) Despite a significantly higher prevalence of IHD in Māori vs non-Māori, intervention rates for Māori are low. (138, 161) Combinations of rurality, Māori ethnicity, and socioeconomic deprivation reflect groups with increasingly poor access to services including coronary angiography. (20, 162-165)

ETT is a relatively low-cost, non-invasive diagnostic test that has the potential to be widely available at a community level. A recent Australian study looking at the utility of ETT in a remote setting concluded that ETT is a particularly useful tool for the diagnosis of IHD in areas where onsite specialist cardiology services are limited. (166)

Using Ministry of Health (MOH) Rural Innovation Funding we provided an ETT service for two different rural communities (Central Otago and Hokianga), from their respective rural hospitals for 12 months. The tests were conducted by specifically trained local medical and nursing staff for patients referred directly by their GP.

The aim of the MoH-funded ETT service project was to improve access to ETT for these communities in a way that was cost-effective and did not compromise standards of care.

Methods

Background

The catchment population of Dunstan Hospital is approximately 25,000, encompassing Central Otago District and the Wanaka part of the Queenstown Lakes District. It is classified as rural/remote, (Rural Ranking Score (RRS) between 55 and 90). Six percent of the population is Māori. It has deprivation indices ranging from 2 to 7. Dunstan Hospital is operated by Central Otago Health Services Ltd (COHSL). Services include a generalist inpatient unit and a range of visiting specialist outpatient clinics. Base hospital and interventional cardiology services are provided 200 km away at Dunedin Public Hospital, Southern District Health Board (SDHB).

Prior to this project, patients needing an ETT were referred to the visiting cardiology clinic or, if necessary, admitted acutely to Dunstan Hospital. ETTs were conducted as part of the cardiology clinic and occasionally for in-patients. Local staff supervised the tests, all of which were then read by a Dunedin based visiting cardiologist.

The Hokianga area is rural/remote with a RRS of 65. The population is 6500, 74% of the population is Māori and the deprivation index is 10. The Hokianga Health Enterprise Trust (HHET) provides integrated health services for the area, including the hospital in Rawene. Base hospital services are provided 130 km away at Whangarei Hospital, Northland District Health Board (NDHB). The nearest interventional cardiology centre is 280 km away in Auckland. With the exception of emergency transfers, there is no direct referral pathway from Rawene Hospital to Auckland.

Visiting medical clinics (every second month) are part of the small range of outpatient clinics provided at Rawene Hospital by specialists from Whangarei Hospital. There is no on-site ETT equipment at Rawene Hospital. Prior to this project, Hokianga patients needing an ETT were first referred to a specialist outpatient clinic either at Rawene or Whangarei and would then have to travel to Whangarei Hospital (or occasionally to Kaitaia) for the ETT. Those requiring an ETT acutely were transferred to Whangarei Hospital.

Description of the service

Clinical protocols were drawn up by the rural hospitals with input from the participating specialists, according to established guidelines. (167) General Practitioners were advised of the referral process by letter. A standardised clinical record form was completed by the generalist for each ETT.

ETT clinics were held once a week at Dunstan Hospital using onsite equipment. ETT clinics were held every 6-8 weeks in Rawene coinciding with the visiting general physician's outpatient clinics. The same physician brought portable ETT equipment from his practice and made it available to Hokianga Health to use on this project, free of charge, in conjunction with an onsite treadmill. At both sites the tests were supervised by local generalist doctors and nurses. Testing commenced in September 2011 and continued through to November 2012 (Dunstan) and September 2012 (Rawene).

At Dunstan Hospital tests were read by a rural hospital generalist. The generalist provided a report for those tests where he felt confidently able to do so. Equivocal tests were sent on to the cardiologist for reporting. At Rawene Hospital, all reporting was done by the rural hospital generalist and each report verified by the physician on the day. All reports were sent to the patient's GP and to the referring doctor (if these were not the same). In both Dunstan and Rawene, the majority of patients were referred back to their GP to discuss their results and for ongoing management. On occasions, where clinically indicated, the patient was referred directly for specialist care from the ETT clinic. With clinics only possible every 6-8 weeks in Rawene, any referrals which were deemed more urgent were referred to Whangarei Hospital.

Study design

In this study we documented the patient outcomes [ongoing GP management, referral to cardiologist, percutaneous intervention (PCI), Coronary Artery Bypass Grafting (CABG)]; audited the reporting of ETT by generalist doctors; determined the tangible costs and attempted to determine whether or not there was any rural-urban difference in the utilisation of ETT.

Ethics committee approval was obtained from the Lower South Regional Ethics committee with respect to the reading of the tests LRS/11/EXP/002.

Data was collected from the standardised clinical record form including the reason for referral, test result, patient disposition post-ETT and basic demographic data. We categorised each test result using conventional criteria. (167, 168) These data were then collated, reviewed and tabulated.

An audit was undertaken of the ETT reports generated at the Dunstan site. In cases where the rural generalist did not feel confident about finalising the report, a provisional local report and the test were sent to the cardiologist for formal reporting. The provisional report and the cardiologist's report were compared.

An additional 25 tests where only a local report had been generated were sent to the cardiologist for formal reporting at the end of the study. The tests were ordered according to the day and time they were performed and every sixth test was selected. The cardiologist report was then compared to the locally generated one. The cardiologist was blinded to the local report.

A simple financial analysis was undertaken to determine the tangible costs of the service. We planned to collect data from the relevant DHBs on the utilisation of ETT one year prior to and during the project. The intention was to identify any rural urban disparities and the impact this study had on these disparities.

Results

Patient demographic, referral and outcome data

Over a period of 12 months, 202 ETTs were carried out at Dunstan Hospital and 33 at Rawene Hospital. Three (1.4%) of the Dunstan patients and 22 (67%) of the Rawene patients identified as Māori.

The most common reason for the ETT was for diagnosis in patients with suspected IHD. A smaller number were referred because of arrhythmia or risk assessment in a patient with known IHD.

At Dunstan, 31 patients (15%) had a positive test result. Eighteen out of these 31 patients were referred directly to the public cardiology clinic (one was admitted acutely to Dunstan Hospital first), and another 7 were referred to a private cardiologist. The remaining 6 were returned to GP care following a discussion between the rural hospital doctor and the cardiologist.

Seventeen of the patients with positive tests proceeded to angiography and of these five had PCI, four had CABG and eight had angiograms with no flow-limiting stenoses (NFLS). Four patients (3%) with negative tests were also subsequently seen by cardiologists and one went on to have an angiogram with NFLS. Five of the 12 patients with equivocal tests were referred to cardiologists (two public and three private). Only one of these patients went on to have angiography (the result showed NFLS). All the remaining patients returned to their GP for follow up.

At Rawene, two patients (6%) had positive tests; both were seen by the visiting physician on the same day as the ETT and referred directly to Auckland for angiography. One was referred urgently and subsequently underwent CABG. The other was referred semi-urgently; the angiogram showed NFLS.

Of the 21 negative tests (63%), all but one were returned to GP care. One patient with a negative ETT at full workload was referred to cardiology in view of a suspicious history despite the negative ETT, was referred on for angiography and went on to have PCI.

Table 21: ETT and patient outcomes in Rawene and Dunstan Hospitals

Dunstan Hospital		Referred to:				Angiography / Intervention				
	N	GP	Private Cardiologist	Public Cardiologist	Admit Ward	Urgent	Routine	No FLS	PCI	CABG
Test result										
Negative	153	149		4		1		1		
Positive	28	3	7	18	1	1	16	8	5	4
Symptom positive	3	3								
Equivocal	12	7	3	2			1	1		
Arrhythmia	2	1								
Suboptimal	4	4			1					
Total	**202**	**167**	**10**	**24**	**2**	**2**	**17**	**10**	**5**	**4**
Rawene Hospital		Referred to:				Angiography / Intervention				
	N	GP		Physician		Urgent/ Semi-urgent	Routine	No FSL	PCI	CABG
Test result										
Negative	21	20		1			1		1	
Positive	1			1		1				1
Symptom positive	1			1		1		1		
Equivocal	1			1						
Arrhythmia	2			2						
Suboptimal	6	3		3						
Exercise capacity	1			1						
Total	**33**	**23**		**10**		**1**	**1**	**1**	**1**	**1**

Two patients had an arrhythmia during the ETT, were seen by the physician on the same day and referred for further investigations. Six tests (18%) were suboptimal, where the patient was unable to exercise long enough to get to their target heart rate. Three of these were referred on for further testing after discussion with the physician. Please refer to Table 21.

Audit – reporting of test results

The generalist doctor reporting the Dunstan tests felt confident in providing a final report for 149 (74%) of the tests. For 53 tests (26%) (which were predominantly equivocal tests), the generalist wrote a preliminary report before the test was sent on to the cardiologist for definitive reporting. For the majority of these 53 tests (39 tests, 73%), there was no variation between the rural hospital generalist's preliminary report and the cardiologist's final one. For 11 tests (23%) the cardiologist downgraded the test (changed the result from equivocal to negative or positive to negative). For three tests (6%) the cardiologist upgraded the report.

There was 100% agreement between the local report and the cardiologists review for the 25 locally generated final reports that were randomly selected for audit at the end of study.

Rural-urban differences in ETT utilisation

We asked for domicile data on all patients receiving publicly funded ETTs in the year preceding the project and for the 12 months of the project. The SDHB was unable to retrieve this data from their systems because the ETT data is not collected in their main patient management system. Limited data was obtained from the NDHB from which an estimated ETT rate for Hokianga residents and urban Whangarei residents for 2010/11 and 2011/12 was extracted (see Table 22). This does not include the ETTs done at Rawene during this project. The utilisation rate for the urban Whangarei population was more than 1.5 times that of the rural Hokianga population.

Table 22: Accessibility

District	Distance to ETT (km)	Closest ETT	ETT/1000 pop (2010–11)	ETT/1000 pop (2011–12)
Whangarei central	0–15 km	Whangarei Hospital	5.9	7.1
Hokianga	60–160 km	Whangarei or Kaitaia Hospital	3.8	4.4

Financial analysis

We calculated the direct costs of the service including doctor and nurse time, equipment costs, consumables, and cardiologist/physician oversight. The cost per test at both Dunstan

($132.50) and Rawene ($200) was considerably less than the national price of $281.13 (community referred tests - cardiology; purchase unit code MS00045 in the National Non Admitted Patient Collection [NNPAC] 2015).

The estimated real cost at Rawene was higher than at Dunstan due to the lower volume, the cost of loaning portable ETT equipment, and the specialist's reading of every ETT test. The actual cost during the project was lower in Rawene because the specialist provided his services free of charge. Nearly all of the patients referred to these rural services would otherwise have been referred to specialist cardiology services. The national price for a cardiology First Specialist Assessment (FSA) in 2012 was $429.49.

Comparing the cost the system would have incurred for these patients had they all been referred to a specialist cardiology service and undergone ETT (using the national prices), we can demonstrate a potential savings of over $125,000 for this small cohort of patients. Please see Tables 23 and 24 below for a summary of this information.

Table 23: Estimated cost of rural generalist ETT followed by FSA if required

Rural generalist ETT followed by FSA if required				
No. of patients	**Dunstan ETT**	**Rawene ETT**	**Referred to FSA**	
202	$132.50 per patient			$26,765.00
33		$200.00 per patient		$6,600.00
20	(18 patients)	(2 patients)	$429.49 per patient	$8,589.80
Total cost to system				**$41,954.80**

Table 24: Direct referral for ETT/FSA estimated cost

Direct referral to FSA for ETT using national prices				
No. of patients	**Dunstan ETT**	**Rawene ETT**	**Referred to FSA**	
202	$281.13 per patient		$429.49 per patient	$143,545.24
33		$281.13 per patient	$429.49 per patient	$23,450.46
Total cost to system				**$166,995.70**

Discussion

Over a period of 12 months we provided a cost-effective local generalist ETT service for two rural communities. Though the organisation of the service at the two hospitals necessarily differed to fit existing local services and available resources, the essence of both was an easily accessible service provided by local clinicians.

Central to both was collaboration between the DHB and the local trust-operated rural hospital, and integration between primary and secondary care. This, along with the option to refer to private cardiology services (Dunstan), and an innovative link-in from private practice (Rawene), resulted in a more seamless patient journey and shifted care ‘closer to home’.

Testing at both sites showed that the majority of patients did not require onward referral to specialist services, providing instead, useful information for the GP to continue to manage these patients in the community. For example, the information from the ETT report could support intensified medical management of IHD or a non-cardiac cause.

Clinical judgment about a patient’s ongoing symptoms over-rules an ETT result because of the test’s limited sensitivity as was the case here for one Rawene patient. Our negative ETT rate is consistent with that reported elsewhere. (168) Our outcomes agree with previous publications suggesting that an appropriately trained and experienced generalist doctor is capable of safely reporting the majority of ETTs. They are also able to recognise those tests where the reporting is less straightforward and send them on to a cardiologist for further assessment and reporting. (169)

Cost

ETT is no more costly to the health system overall when run in a rural area, and significantly less costly for the patient. Travel to a distant hospital for the patient (and their support networks), means not only direct travel and often accommodation costs but also time off work and other duties. Further, public transport is sparse or absent in rural areas. For the Hokianga community there is added meaning to cost of travel from a cultural perspective: Māori have intrinsic relationships with whenua (land and identity), their whanau (family contribution to their health), and tupuna (elders who provide security, wisdom and guidance) which are generationally driven and is how Māori value their living environment which itself sustains life. Maintaining these values through kaitiakitanga (caring) sustains the people, therefore being moved from a trusted health service to distant health services causes anxiety in regard to Kaitiaki o te kainga (caring for home and land) and can further impact on health outcomes.

Our financial comparison of specialist delivered ETT vs. generalist delivered ETT is subjective. When DHBs fund providers they may use the purchase unit price, or the actual cost of delivering the test. Whilst this may be subject to negotiation with the provider, the difference is not material. We can identify no additional costs to the District Health Boards by providing this service rurally.

Rural vs urban differences in ETT utilisation

We were not able to obtain data to assess the geographic variation in the utilisation of ETT in the SDHB region or the impact that this study may have had on this. The data obtained from the NDHB was limited. We also noted that the way rural residents' addresses are recorded in hospital systems is frequently not a good indicator of where the person actually lives, but instead often is their postal address—e.g. the closest store which could be several tens of kilometres away.

A recent NZ study identified large 'rural versus urban' disparities in the utilisation of computed tomography. (31) Good data is needed if the urban vs rural disparities in access to services are to be identified and corrected; DHBs should be encouraged to collect this data.

Implications for rural services

Though we looked at only two rural areas and access to a single diagnostic test, this project illustrates the complexity and variation in systems within NZ in which rural clinicians and patients are required to operate. It suggests that the degree to which services are integrated across primary, secondary and tertiary care at the presenting rural facility has an important role in the delivery of downstream healthcare for that specific community.

Not only do these services and pathways seem fragmented and poorly co-ordinated, as has been noted elsewhere, (170, 171) they do not appear to be related in any way to patient need.

An integrated regional approach to the provision of ETT services is needed if disparities in access are to be remedied. (154, 167, 168) A collaborative approach that involves local health service providers in clinical pathway development from the earliest stages will help ensure the service is locally appropriate and sustainable. (69, 151)

Transferability

We believe this is a sustainable way of delivering ETT services to rural communities that provides savings to the health system, improves access for rural patients and may help overcome some of the disparities in access to cardiac investigations faced by rural patients.

This service is capable of being replicated at other rural sites pending small investments in rural generalist training and equipment.

-End of published manuscript-

Addressing the evaluation framework

The primary performance measures considered in this service evaluation are *appropriateness* of the service (as measured by quality and safety), and *efficiency* (as cost effectiveness). Other performance measures, and their indicators, are considered to a lesser degree.

The financial analysis demonstrates that the service is *efficient* when compared to urban-based services, despite the capital costs and low volumes. Further, the proportion of tests that were negative (comparable to urban-based services) suggests that the local service is not resulting in over-servicing, another indicator of *appropriateness* and *efficiency*. The financial analysis did not consider the savings to patients by not having to travel to the city to access ETT. In the study undertaken in Central Otago (discussed in the introduction), the financial costs borne by rural patients to access an urban-based specialist outpatient appointment were in excess of $700 per visit. The costs associated with travelling from remote parts of the Hokianga to Whangārei for an ETT would likely be similar. These costs are far greater than the costs to the healthcare system in providing the test (either locally or at the base hospital).

The audit confirmed that the rural generalists were able to accurately report the majority of the exercise tests and, importantly, they were able to identify the smaller number of equivocal tests that would benefit from cardiologist review. From a quality and safety perspective, the service was therefore *appropriate.*

The limited utilisation data that was available suggests that the Hokianga community has considerably poorer access to ETT than urban Northland patients. This is evidence of unmet need and another indicator that the decision to establish a local service was *appropriate.* The small numbers and infrequency of the service meant that the impact of a local ETT service on utilisation rates would be relatively small. However, for the individual patients who had an opportunity to access the local service, the impact would have been significant.

The study details the outcomes for patients who had ETTs performed. It appears that the service was *effective* and had the potential to improve outcomes. Howevever, the study was not designed to compare outcomes, and we have no way of determining whether or not patients would have had the same or different outcomes if the only option had been to travel to the city for an ETT.

Addressing background issues

The study adds to two important background issues to the thesis that were raised in the introduction: problems with the data necessary to make rural-urban comparisons in health in

NZ; and the importance of rural generalists and urban specialists collaborating to provide rural health services.

Despite repeated attempts, we were unable to obtain data on ETT utilisation from the Southern District Health Board (SDHB). As seen in chapter 2, the SDHB serves a large geograhic area in which more than a third of the population is rural. The SDHB has traditionally concentrated its complex diagnostic services (including CT and ETT) in the region's two urban centres. Given the nature of its catchment, it is perhaps surprising that the SDHB does not routinely collect data to monitor the equitable delivery of its services across the region. It is also not possible to extract this data from national health data sets.

The description of this service highlights the importance of close collaboration between local rural generalists and distant urban specialists when providing services in a rural area that, in the city, would be routinely provided by specialists. This builds on the theme that appeared in the introduction (audit of cardiology outcomes at Dunstan hospital (24)), and runs to a greater or lesser extent through all the services studied in this thesis: urban-based radiologists undertake the reporting CT performed by the Oamaru rural scanner (chapter 4); the complicated quality assurance needed to monitor rural POC testing by urban laboratory technicians; the urban sonographers, echocardiographers, cardiologists and emergency physicians providing the point-of-care ultrasound training for rural generalists.

Chapter 8: Scope of point-of-care ultrasound practice in rural NZ

Context statement

The largest study in this thesis is an evaluation of the point-of-care ultrasound (POCUS) service in six NZ rural hospitals. The resulting publications form chapters 8 to 12.

The aims of the thesis and research questions with respect to rural POCUS in NZ are addressed in the context statement for chapter 9. Chapter 8 addresses the specific question '*What is the scope of point-of-care ultrasound (POCUS) being practised by generalist doctors in rural New Zealand?',* and includes other descriptive information of the POCUS services being evaluated. This provides important background information for the subsequent chapters.

In chapter 8, a mixed methods descriptive methodology is employed. Data is collected on the type and frequency of POCUS scans being performed. The findings of a simple survey of the participating doctors are also presented. Questions collected information on the impact of POCUS on clinical practice, quality assurance and equipment issues, and the level of support received from radiologists, sonographers and colleagues.

Nixon, G. Blattner, K. Koroheke-Rogers, K. Muirhead, J. Finnie, W. Lawrenson, R. Kerse, N. Scope of point-of-care ultrasound practice in rural New Zealand. J Primary Health Care. 2018;10(3):224-36

Introduction

Ultrasound was traditionally the domain of sonographers, specialist radiologists and cardiologists. This has changed with the emergence of point-of-care ultrasound (POCUS), which is being used by a range of specialties for both diagnosis and to guide procedures. (172) The potential diagnostic value of POCUS may be greatest in rural settings where access to formal ultrasound, and imaging modalities generally, is limited.

POCUS has been advocated both in the rural setting (173) and in the hands of generalist hospital doctors dealing with inpatients. (174) However, apart from one small study of 43 patients in a rural emergency department in The United States of America (136), surveys of rural physicians in Ontario (175) and Quebec (176), and others in very remote or wilderness settings, (172, 177, 178) there are no published papers that describe the scope of POCUS being practiced by rural generalists, or its impact on patient management in the rural context.

Rural doctors are learning POCUS skills. This is evidenced by the more than 250 graduates of the University of Otago New Zealand Postgraduate Certificate in Clinician-Performed Ultrasound (PGCertCPU) since its inception in 2006. (179) The Australian College of Rural and Remote Medicine along with other providers run similar courses in Australia. (180)

Rural generalist medicine encompasses primary, inpatient as well as emergency care and a number of advanced skill sets. (60) A consequence of broad scopes of practice is lower volumes of any particular presentation or procedure. This raises important issues around maintaining competence and patient safety. We are unaware of efforts by any professional college or credentialing body to recognise a scope of practice or set standards for rural POCUS, although policies have been developed by the Australasian College of Emergency Medicine for their membership. (181)

The aim of this article is to provide an overview of diagnostic POCUS in a sample of New Zealand rural hospitals. The study measures the volume and range of POCUS examinations being undertaken and using a questionnaire provides perspectives of the impact of POCUS from the point of view of participating doctors. This analysis is part of a larger study that evaluates the ability of generalist rural doctors to obtain and correctly interpret POCUS images and the impact on patient care. The intention is to collect information that will inform appropriate training, policy and resourcing for rural POCUS.

Methods

The quantitative and qualitative data in this mixed methods paper are analysed concurrently but separately, and integrated during interpretation, described as an ‘integrative process’. (182)

The study was conducted in six New Zealand (NZ) rural hospitals. These hospitals represent the geographic and socio-demographic diversity of rural NZ, collectively accounting for 25% of all NZ’s rural hospitals. (23) They are staffed by rural general practitioners and rural hospital generalists. None of the hospitals have surgical capabilities or on-site surgeons. Two of the hospitals are integrated with general practice. The catchment populations and distance to the nearest base hospital are presented in Table 25. All the rural doctors practicing POCUS in these hospitals during the study period were eligible for inclusion and invited to join the study.

Part 1 Quantitative:

Each time they undertook POCUS as part of their routine clinical duties, the participating doctors completed a form (appended) that, in addition to the patients age, ethnicity and gender (via the National Health Index Number), captured details about the type of POCUS examinations, the POCUS findings, and whether or not the doctor asked for the images to be reviewed. Scans undertaken principally for training or to guide procedures were not included in this study. Participating doctors were strongly encouraged to record all scans as performed over a 9 month period in 2012.

Statistical analysis was undertaken using SPSS version 23. Descriptive statistics were used to summarise the number and type of POCUS examinations undertaken as well as the characteristics of patients. The differences in scan frequency between the hospitals were corrected for doctors working in multiple hospitals using a generalised linear mixed model with Poisson as distribution and the interaction between doctor and POCUS scan type as random term. The Poisson distribution with the log link was chosen, as this regression can be used for multinomial distributions. (183) The Function glmer in the R package lme4 was used for the analysis. (184)

Part II Qualitative:

Three months after the completion of the quantitative study participants were asked to complete a questionnaire, which included questions about the impact of POCUS on patient management; quality assurance and credentialing, and the implementation of POCUS in a rural hospital. (Appended) The written responses were entered into an excel spreadsheet according to the categories used in the questionnaire. After review by the research team responses were collated into categories that related to the original questions capturing the main issues. Participant responses were reported as summaries and quotes. To maintain participant anonymity, all respondents were designated a number (1-17) and were referred to throughout by this coding e.g. Respondent 5 or R5.

Ethics approval was obtained from the NZ Multi Region Ethics Committee MEC/10/09/091 and in line with this consent was obtained from the participating doctors.

Results

Quantitative:

Twenty eight doctors were enrolled in the study; one eligible doctor declined to participate. POCUS scans were conducted and forms completed for 1044 patients. Of these 30 were excluded because it was not possible to identify the patient because of incorrect or inadequate information on the form. Scans from 1014 patients were included in the study. Many scans involved more than one type of ‘examination’ (e.g. gallbladder and kidney). The 1014 patients underwent 1247 examinations.

Age data was missing for 16 patients. The youngest patient scanned was 1 year of age, the oldest 102 years and median age was 63 years. Ethnicity data was missing for 8 patients. Overall 78% were European, 20 % Māori and 2 % other.

Table 25: Characteristics of the study hospitals and patients

[a] Number of general medical inpatient beds.
[b] Distance to the nearest base hospital by road in km. The bases hospitals covering Hospitals 1,2,3 and 5 do not have tertiary services such and interventional cardiology or vascular surgery. The tertiary hospitals providing these services is a further 160 to 200 km distant. km = kilometres.
[c] Rural hospitals in NZ do not have clearly defined catchment boundaries. These figures were obtained from local hospital administrators. Approx. = approximate. Pop. = population
[d] Māori as a percentage of catchment population, % = percent.
[e] Number of medical staff practicing ultrasound at the time and therefore eligible for enrolment in the study.

	North Island Hospitals			South Island Hospitals			
	1	2	3	4	5	6	All
Hospital Characteristics:							
Bed Numbers[a]	10	15	12	30	10	24	
Distance to Base Hospital (km)[b]	126	55	57	112	187	200	
Approx. Resident Catchment Pop.[c]	6,500	36,500	13,500	21,000	17,500	26,000	
% Māori in Catchment[d]	74	41	31	4.5	5.4	6	
Number POCUS Active Staff[e]	3	3	5	1	8	8	28
X-ray available 24hrs/7days	N	Y	Y	Y	Y	Y	
Visiting Sonography	N	Y	N				
In House Sonography	N	N	N	Y	Y	Y	
In House Computed Tomography	N	N	N	Y	N	N	
Characteristics of Patients Scanned:							
Median Age in years	66	57	61	50	38	68	63
Percent Māori %	64	44	21	5.3	4	2	20
Percent inpatients[f] %	67	83	35	23	40	87	66
Total Number Patients Scanned[g] n	180	104	127	76	113	414	1014
Total Number POCUS Examinations n	212	121	144	87	134	550	1248
Total Number POCUS Findings n	238	142	159	98	156	616	1409

POCUS = point of care ultrasound.
[f] Percentage of patients scanned who were inpatients at the time. The remainder were emergency department or General Practice clinic patients
[g] Total number of patients scanned and included in the study.

The frequency of each POCUS examination is included in Table 26. The most commonly performed examinations were cardiac scans and those assessing intravascular volume (inferior vena cava diameter and jugular venous pressure).

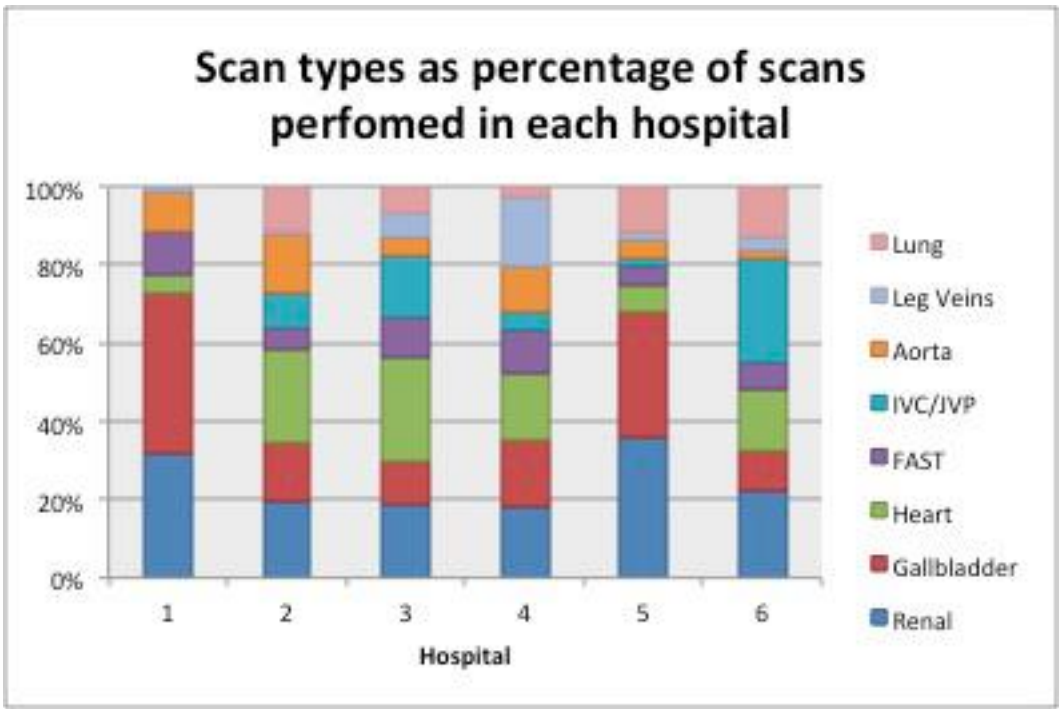
Table 26: Frequency of POCUS examinations

POCUS Examination:	Commonly sought findings	Number	Percentage
Cardiac	Pericardial effusion, Left ventricular function, Chamber size	226	18
IVC/JVP[a]	Hypvolemia and volume overload	172	14
Gallbladder	Gallstones	163	13
Kidney	Hydronephrosis	139	11
FAST[b]	Free intraperitoneal fluid	86	7
Bladder	Urinary retention	80	6
Leg veins[c]	Deep vein thrombosis	70	6
Subcutaneous[d]	Abscess, Foreign bodys	68	6
Aorta	Abdominal aortic aneurysm	65	5
Lung[e]	Pleural fluid, consolidation, pulmonary oedema	63	5
Pelvic [f]	Intrauterine pregnancy	55	4
Abdomen[g]	Ascites	28	2
Musculoskeletal[h]	Fractures, tendon rupture	23	2
Uncommon[i]	Testicular torsion, Retinal detachment	9	1
	Total	1247	

[a] IVC/JVP = Jugular venous pulse and inferior vena cava for volume assessment.
[b] FAST = Focused Assessment with Sonography for Trauma looking for free intraperitoneal or pericardial fluid
[c] Deep venous system above the knee looking for thrombosis
[d] Collections and foreign bodies
[e] Pleural fluid, pneumothorax, pulmonary oedema or consolidation
[f] Intrauterine pregnancy, free fluid, ovarian cyst
[g] Ascites
[h] Fractures, tendons
[i] Testes, eyes

Even after correcting for variation between the participating doctors there remained a significant variation between the hospitals in the frequency of scan types that were performed ($p<0.001$). This is illustrated in Figure 9.

Figure 9: Scan types



In only 3% of cases did the participant review the images with a colleague in person or by sharing them electronically. If this occurred it was most likely to have been with a sonographer, an echocardiographer or a cardiologist.

Qualitative:

Twenty three of the participating doctors were still working in the study hospitals when the questionnaire was undertaken; 5 had moved to work elsewhere. Seventeen completed and returned the questionnaire. (17/23, 74% uptake).

The key findings are summarised in three main categories. Examples in the form of quotes are presented in Table 27 for each category.

Table 27: Main categories with supportive examples taken from participant questionnaire.

Category	Example 1	Example 2	Example 2
1. Clinical practice	'…it has become a normal part of what we [clinicians] do here. [Now I]… use it [POCUS] more than my stethoscope.' R10	'…, acutely unwell patients with multiple medical problems … volume status is often hard to assess clinically and IVC [inferior vena cava] is very helpful especially serial scans, in determining management… [it] allows more confidence in managing cases here.' R1.	'[POCUS]…adds a level of skill and experience that allows doctors to broaden their arsenal of diagnostic tests, especially in a small hospital where access to imaging is limited' R3
2. Quality assurance and training.	'…discussion and looking at each other's images is good but lack of formal [QA] process is an issue.' R2	'…operational support for technical aspects …not well understood (*by rural hospital service*) so doctors end up doing that too.' R6	'…was it [the PGCertCPU course] adequate: yes, but my practice since hasn't been…I find it is something you have to do every day even when you are busy otherwise you don't have the skills when you need them.' R5
3. Colleague perception.	'… [with] other doctors asking me to do a scan - the limitations have to be clear and the question asked has to be clear for it (POCUS] to work.' R14	'AB… [a radiologist who teaches on the PGCertCPU course] is [supportive], the others not so particularly but [they're] not obstructive.' R10	'…good support from echo technician and cardiologist who visit us (rural hospital) regularly.'R1

Clinical Practice: POCUS made a valuable impact on patient management largely by adding to diagnostic certainty. Respondents enjoyed using the new and practical POCUS skill and regarded scanning as an extension of their clinical examination.

Training and Quality assurance: Fifteen out of the 17 doctors surveyed were graduates of the University of Otago Postgraduate Certificate in Clinician Performed Ultrasound, a yearlong programme that includes three workshops and an online learning platform. (179) One had attended a week long course in Australia and the other had learnt ultrasound as part of his undergraduate medical education in Germany.

Respondents were conscious of POCUS scope limitations and the need for ongoing training. Respondents mentioned the pressure of ongoing maintenance of their competency in POCUS given the already challenging scopes of practice in rural hospitals. None of the respondents were aware of any formal POCUS Quality Assurance (QA) or credentialing systems within NZ. Respondents commented on the need for their hospitals to incorporate systems for set up and maintenance of POCUS equipment (including download, storage and transmission of images) into routine operations.

Colleague perception: While some respondents experienced negative responses from urban specialist colleagues, others indicated a growing acceptance by these same specialists of POCUS and its value in the rural context. Particular support was noted from specialists who regularly visited the rural centres.

While the POCUS trained rural clinicians had a good understanding of their POCUS scope and its limitations, rural colleague perception of POCUS scope varied. Several respondents found referrals from onsite colleagues who were not POCUS trained difficult to manage because of the expectation they perform a stand-alone ultrasound examination rather than incorporating it as part of a clinical assessment.

Respondents valued being involved in the research and more than half of the respondents specified the rural ownership of the study was key in prompting their participation and interest in the research.

Table 28: Recommendations for establishing a rural POCUS service, developed from questionnaire responses feedback.

1. Consult with existing rural POCUS services for advice.
2. Obtain quality equipment fit for purpose.
3. Ensure rural focused POCUS training for rural doctors incorporating likely scope of practice.
4. Establish responsibility for supplier contact, software and data storage and maintenance schedule for equipment
5. Define clear guidelines for POCUS use and referral of patients to the POCUS clinician. Ensure these are clearly communicated to relevant staff.
6. Incorporate and start using POCUS as soon as is practicable.

Discussion

The notable quantitative findings in this study show that the scope of rural POCUS is broad, relatively complex and varies considerably between hospitals. Cardiac scans, arguably the technically most difficult, were the most commonly performed; while FAST and aorta, more straightforward POCUS examinations, and the most commonly performed scans in urban emergency departments (176, 185, 186), were only the 5th and 9th most frequently undertaken in this rural study. This broad scope of rural POCUS mirrors the scope of rural generalist medicine (60), and a context that is typified by poor access to complex diagnostic imaging. (67)

This same breadth and complexity of POCUS will underlie the concerns the participants expressed about the limitations of their personal POCUS skills and the lack of formal quality assurance processes and opportunities for ongoing training.

The absence of a recognised scope and clinical governance for rural POCUS may also be responsible for other study findings; the absence of systems to maintain machines and download and store images; the limited understanding of rural POCUS by healthcare managers and urban colleagues; low rates of image review with colleagues or specialists; and the large variation in frequency of POCUS examinations between the study hospitals. The latter finding was unexpected and cannot be explained by differences in training, as most of the participants graduated from the same university based POCUS course. Equally while there are differences in the demographics of the hospital catchment populations these are insufficient to explain the variation. Each hospital is in a sense ‘doing their own thing’.

The study recorded only a very small number of obstetric scans. This finding was expected and reflects how few generalist doctors in NZ still practice obstetrics. (187) This may represent a missed opportunity for NZ rural doctors and midwives. Australian rural doctors consider obstetric scanning to be an important part of their POCUS practice. (188)

Māori comprised 20% of the patients scanned but 27% of the hospital catchments population base. Potential explanations include the younger age profile of the Māori population but older age of patients being scanned. In one of the northern communities 88% of those under 25 but only 61% of those over 45yrs are Māori, and the median age of those scanned was 66 yrs. The hospital catchment populations are estimates obtained from local hospital managers. This further complicates these calculations and makes it difficult to generate age-standardised rates. Two of the southern hospitals are in tourist centres and it is unknown how many of the patients scanned were non-residents. The institutions and their clinicians must however consider the possibility that these results reflect systemic bias and future audits and studies designed to test this will be needed. [*A further analysis of this data, looking at the northern communities in isolation, is included in the concluding chapter of the thesis*].

In this study the North Island hospitals were smaller, further away from tertiary services and had less access to imaging than their South Island counterparts (see Table 23 for a summary). These same hospitals serve large Māori populations. NZ Māori are disadvantaged in health outcomes and access to health services and rural Māori may face even greater disadvantages than their urban counterparts. (25) This underscores the need and importance of equitable and safe POCUS services, to all NZ rural communities.

The rural ownership of this study was notably important for the participants and supports previous findings that research developed in consultation with rural communities and healthcare providers, and embedded in rural areas, is more likely to align with the healthcare aspirations of those rural communities. (189)

This is the first study to describe the use of POCUS in rural hospitals and one of the largest studies to describe its use in day-to-day clinical practice in any context. The qualitative component of the study is limited by the methodology; collated responses from a written questionnaire lack the depth that could be gained from other qualitative research methods. The real world nature of the study and geographic and demographic spread of the hospitals are strengths of the study. While doctors were strongly encouraged to include all the scans they undertook during the study period we were unable to ascertain how many examinations were not reported. POCUS is an evolving field and it is likely the skills of rural practitioners will have developed further since this study was undertaken in 2012. However the scope of POCUS taught to PGCertCPU students in 2018 is, apart from the addition of some lung ultrasound, unchanged from 2012. (190) More importantly quality assurance and credentialing processes for POCUS in most rural hospitals have not progressed.

In light of these study findings the authors recommend that clinical governance be implemented for rural POCUS in NZ, including safe scopes of practice, credentialing and quality assurance. Given the size of New Zealand's hospitals it may be more appropriate for this to be provided by the hospitals collectively or through the Royal NZ College of General Practitioners. This process should be informed by further rurally based research into the outcomes of POCUS.

Data collection form

DIAGNOSIS/VOLUME

DATE:……………………

TIME:…………………..

Stick patient label here or

Patient Name:…………………………………………………

NHI………………………………

Clinicians initials:

Inpatient / Outpatient

Ultrasound quality:

Good ☐ **Adequate** ☐ **Not diagnostic** ☐

Pre-test Likelihood | **Post-test likelihood**

Potential Diagnosis:

100% | 50% | 0% (pre-test) — 100% | 50% | 0% (post-test)

Potential Diagnosis:

100% | 50% | 0% (pre-test) — 100% | 50% | 0% (post-test)

Volume Assessment. What is the patients problem e.g. trauma, heart failure?:

Severe volume overload | Normovolemic | Severe hypovolemia (pre-test) — Severe volume overload | Normovolemic | Severe hypovolemia (post-test)

Ultrasound Findings:

Pretest | **Post test**

What do you plan to do with the patient?

Transfer by air | 50/50 | Transfer by road | 50/50 | Admit rural | 50/50 | Discharge (pretest)

Transfer by air | 50/50 | Transfer by road | 50/50 | Admit rural | 50/50 | Discharge (post test)

In what other ways has the test altered patient management? (Include treatment, follow-up, referrals for other imaging; mention calling in out of hours radiology or lab or other referrals):

Did you get the images reviewed? ☐ If yes provide details.

Questionnaire for participating doctors

1. **Clinical experiences**

(a) What CPU examinations do you use most often?

....

....

(b) What CPU examinations do you find the **most** helpful clinically and why?..
....
....

(c) What CPU examinations do you find the **least** helpful and why?
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………………………………………….

(d) What CPU examinations are you the most comfortable performing?
……………………………………………………………………………………………
…………………………………………………………………………….
…………………………………………………………………………………….

(e) What CPU examinations do you have the most difficulty performing?
……………………………………………………………………………………………
…………………………………………………………………………….
…………………………………………………………………………………….

2. **Training**

a) What formal training have you received in CPU?

b) Was this adequate?

c) Would you like to receive further or ongoing training in CPU?

d) What type of training is the most useful?

Rank the following (if possible) on a scale of 1 to 4 with 1 being **least** useful and 5 being **most** useful:

- Self teaching (reading could be part of this)
- One-on-one training with a tutor
- Workshop
- Working together with/discussions with colleagues

e) Were you involved in getting CPU up and going in your hospital?

If so, were there any issues in implementing CPU?

f) What advice would you have to others doing the same?

3. **Quality assurance and credentialing**

a) What are the QA and Credentialing systems in place for you?.(if any)

b) Are these systems useful? Please give examples

4. **Equipment and technology issues**

a) Are there issues around the availability of equipment, maintenance, and quality, budgetary constraints, downloading and storing images?

b) How supportive is hospital management for CPU?

c) Do you have the facility to electronically transmit images to base hospital colleagues? Is this happening? Please give examples

5. **Relationships with specialists including radiologists and ultrasound technicians**

a) Are they supportive?

b) Do they look at images for you? Please give examples

6. **Practice**

a) Does doing the CPU impose restrictions on or improve your time management? Please give examples

b) What do you think would be potentially useful extensions of the scope of practice?

c) How does the ability to do CPU affect job satisfaction? Please give examples.

d) What other issues around CPU do you think are worth discussing?

7. **Research**

How have you found being part of this research project?

8 **Administration**

a) How did you and your staff find administrative aspects of the project?

c) How was communication with the university staff?

-End of published manuscript-

Addressing the evaluation framework

The findings presented in chapters 9, 10 and 12 address the performance measures in the Reeve evaluation framework by way of a range of indicators.

In this chapter, the description of the POCUS service throws light on the *accessibility* of the service, and the survey results sheds light on the *effectiveness* of POCUS from the point of view of the participants. The importance of the quality measures, which are considered in later chapters, is emphasised in the participants' survey responses and the scope of practice findings.

Accessibility: Formal ultrasound, performed by trained ultra-sonographers, is available in only a minority of NZ's rural hospitals. (67) No NZ rural hospital has access to formal ultrasound outside normal working hours. Urban-rural disparities in access to ultrasound are therefore likely to be similar to the ones demonstrated in access to CT in chapter 2. The advent of point-of-care ultrasound, performed by clinicians at the beside, has an obvious appeal in rural areas, creating the potential for access to the ultrasound imaging that is immediately available 24 hours a day in urban areas, and as such, a considerable improvement in service *accessibility* and *equity* of access.

In their survey responses, the participating doctors reported that, although POCUS was a valuable additional clinical skill, they found it challenging and were aware of the limits of their ultrasound skills. Many of the participants mentioned the lack of opportunities for ongoing training and the absence of policies in their institutions to support standards of practice, such as credentialing. The scope of POCUS being practised was broad and complex. Most surprising was the large variation between hospitals in the frequency with which different scans were being performed. Taken collectively, these findings emphasise the importance of the quality and safety indicators that are considered in subsequent chapters, to the *appropriateness* of the service.

Addressing community engagement and cultural acceptability when conducting rural research

Earlier studies in this thesis (POC testing and ETT) included an in-depth qualitative evaluation of the rural diagnostic service being studied. These findings, based on interviews with local healthcare providers, highlighted the importance of the local nature of the service in meeting the needs of rural Māori. This was because the service was delivered by people who were part of the community and knew them, working from an institution 'owned' by the community, and importantly for elderly Māori, the local service meant they did not have to leave their land, supports and responsibilities.

Similar principles of community engagement and ownership apply when undertaking rural health research. The POCUS study was funded by a Health Research Council Partnership

Grant. The partners were the University of Otago and the two rural health service providers, Hauora Hokianga and Central Otago Health Services. The participating rural doctors in the POCUS study highlighted the importance of the rural ‘ownership’ of the research. Some of them indicated that one of the reasons they chose to participate was because the research was being led by rural clinicians like themselves, often their immediate colleagues. The value of rural research that is conducted in rural communities by rurally-based researchers has been noted elsewhere. (191)

What is not so obvious in reading the papers in chapters 9 to 12 is the process of engagement with tangata whenua that underpinned this project. This was led Marara Koroheke-Rogers, a Hokianga Māori health worker who was a member of the research team. Marara details this process in a paper that sat alongside the most substantial of the POCUS study papers (chapter 9), when it was published in the Australian Journal of Rural Health in 2018. (81) NZ has well-established guidelines for undertaking health research with Māori. (192) But a separate process, te tomokanga, was needed to engage and develop a partnership with the rural Māori communities involved in this study. This followed their processes of developing relationships. The business of the research (rangahau) could only be considered after this had been completed with each of the participating communities, the relationships formalised, tautoko (approval) obtained from ngā kaumatua (elders), and the project given the blessing that would guide it. (81)

Chapter 9: Rural point-of-care ultrasound: Quality and impact on patient care

Context statement

Chapter 9 addresses research questions that focus on the quality and safety of rural POCUS practice and its impact on patient care: *Does the service meet recognised quality standards? Is it safe? Does the service aid diagnostic decision making? Is the service cost effective? Does the service improve patient outcomes?*

The following study specifically addresses the questions: *Are rural doctors obtaining images of diagnostic quality? How accurately are they interpreting the images they obtain? What impact is POCUS having on diagnostic certainty? What impact is POCUS having on discharge and transfer decisions? Is there evidence of patient harm as a consequence of POCUS? What is the overall impact of POCUS on patient care?*

A combination of methods were used to generate a set of indicators to answer these questions and address the performance measures of the evaluation framework. Participants completed a questionnaire before and after completing the POCUS examination, similar to the questionnaire used in the POC testing study (chapter 5). Questions were asked about the probability of the diagnoses being considered and planned patient disposition. The differences between the pre-test and post-test responses were then used to determine the effect of POCUS on diagnostic certainty and patient disposition. A specialist panel undertook a review of the clinical records, comparing the POCUS findings to definitive findings (often formal imaging) and the overall impact on patient care. A sonographer and echocardiographer reviewed the saved images, assessing image quality and accuracy of interpretation.

Ultrasound is the most operator-dependent of the diagnostic tests evaluated in this thesis, demanding skills in both the acquisition and the interpretation of ultrasound images. Poor image quality or incorrect interpretation can result in an incorrect diagnosis, with the potential for patient harm. The findings presented in chapter 9 (i.e. the breadth and complexity of rural POCUS being practised by rural doctors, the lack of institutional supports, quality assurance, and the large variation in practice between institutions) emphasise the importance of quality and safety measures when evaluating rural POCUS.

Nixon G. Blattner K, Muirhead, J. Finnie, W. Lawrenson, R. Kerse, N. Point-of-care ultrasound in rural New Zealand: Safety, quality and impact on patient management. Aust J Rural Health 2018;26:342-9

Introduction

Point-of-care ultrasound (POCUS) is an increasingly common adjunct to the clinical assessment of patients in the rural setting. The number of rural generalist doctors acquiring POCUS skills and rural health facilities investing in ultrasound machines is growing. (176, 180, 188, 193) This trend is in line with other branches of medicine. (172, 186, 194) The limited access to formal ultrasound and other complex diagnostic imaging, which typifies rural and remote practice, makes POCUS particularly appealing in this context.

At the same time POCUS is an advanced skill set that requires additional training and on-going practice to achieve and maintain safe standards. (194) This can be a challenge for rural practitioners who have fewer local training opportunities and whose broad scope of practice means they deal with low volumes of many presentations and procedures.

New Zealand's (NZ) dispersed rural communities are served by 26 small rural hospitals staffed by rural generalist doctors (23) whose training is overseen by the Royal NZ College of General Practitioners. (59) The majority of these doctors practice POCUS. This study assesses the POCUS skills of a sample of these doctors, both in obtaining and interpreting images. Furthermore, it assesses the impact of POCUS on diagnostic decision making and patient management, with particular reference to disposition (i.e. the decision to discharge vs. admit to local rural hospital vs. transfer to urban hospital either by road or air ambulance).

The insights gained from this study are intended to inform POCUS policy, training and credentialing in rural medicine.

Methods

A combination of methods was used in this study; an audit of POCUS image quality and interpretation, a prospective comparison of POCUS findings to a gold standard and an outcome impact assessment.

All POCUS active doctors (29 in total) in six geographically dispersed NZ rural hospitals, were eligible and invited to join the study. Only one doctor declined to participate. Information was collected by each participating doctor on all the POCUS scans they undertook as part of their routine clinical duties over the 9 month study period in 2012. None of the study hospitals have surgical facilities or surgeons onsite, three have access to formal ultrasound during normal work hours and only one had a CT scanner at the time of the study.

The study included diagnostic POCUS examinations but not those used solely to guide procedures.

A ‘case’ was defined as the clinical assessment of one patient. Many cases involved more than one type of POCUS examination’ (e.g. gallbladder and kidney may have both been scanned). Some examinations included more than one POCUS ‘finding’. For example a cardiac ‘examination’ might have included the findings: pericardial effusion and moderately impaired left ventricular function.

Data was derived from 3 sources; 1) a questionnaire completed by the participants; 2) review of saved POCUS images and; 3) review of clinical records. The data sources used for each study outcome is summarised in Table 29.

Table 29: Methodology and data source for rural point-of-care ultrasound (POCUS) study

Outcome	Source of data	Results reported in:
Self-reported scan quality	Questionnaire	Table 4
Assessed scan quality	Review of Images by specialist panel	Table 4
Scan Interpretation	Findings on questionnaire vs. review of images by specialist panel	Table 4
Accuracy of POCUS findings	Findings on questionnaire vs. definitive findings in clinical in record	Table 5
Impact on diagnostic probability	Questionnaire: change between pre- and post-test probability of principal diagnoses	Figure 1
Change in Disposition	Pre and post-test disposition from questionnaire. Actual disposition from review of clinical records	Table 6 Figure 2
Overall Impact on patient care	Review of clinical records	Table 6

Data Sources

1. Questionnaire:

The participants completed a questionnaire whenever they used POCUS to assess a case. This collected information on the type of POCUS examinations, the quality of the images obtained (self-assessed as either good, adequate enough for diagnostic purposes or non-diagnostic) and the POCUS findings (participants' interpretation of the images).

The questionnaire also asked participants to specify: 1) the percentage likelihood of each of the primary differential diagnoses they were considering (diagnostic probability) and 2) the planned disposition for the patient. Both 1 and 2 were recorded by the treating doctor (participant) prior to undertaking the POCUS ('pre-test') and again after the POCUS scan, in light of the additional clinical information that had been obtained ('post-test'). Changes between the pre-test and post-test assessments were used to determine the impact that POCUS had on diagnostic probability and patient disposition.

2. Review of Saved POCUS Images:

The participants were asked to keep electronic records of their images either as still images or clips. Members of the specialist panel (described below) reviewed all the available images. They categorised the technical quality of the images as either 'good quality', 'adequate quality', 'quality inadequate but still sufficient to make a diagnosis' or 'non-diagnostic' ('assessed scan quality'). They also reviewed the participating doctor's POCUS findings deciding whether or not their interpretation was 'correct', 'partially correct' or 'incorrect' ('scan interpretation').

3. Review of Clinical Records:

Two investigators (KB and GN, both rural generalists) undertook a review of the clinical records of all the cases in the six months following the study period. Where possible, definitive findings of POCUS scans were determined based on either the results of formal diagnostic imaging, the final diagnosis or a review of the saved POCUS images. The 'accuracy of POCUS findings' was determined by comparing these definitive findings with the participants' findings on the questionnaire.

By evaluating the POCUS findings against the information available in the clinical record, the investigator categorised the impact the POCUS had on the patient's management as either nil, some, significant, major or negative. 'Nil' was where the POCUS scan was judged to have had no or minimal impact on patient management and included nondiagnostic scans. 'Some' impact on patient management included altering intravenous fluids or diuretics, confirming a diagnosis that was likely to have been made without the scan or ruling out an important but very unlikely diagnosis. Examples of 'significant' impacts on management included changing the intended patient disposition (e.g. deciding to discharge a patient that might have otherwise been admitted for observation) or leading to a diagnosis that was unclear prior to the scan. To meet the threshold for 'major' impact there had to be evidence that the POCUS avoided major disability or death. 'Negative' impact was any situation in which it appeared the patient would have been better not to have had the POCUS scan; i.e. that it delayed the correct diagnosis or resulted in inappropriate clinical management.

A specialist panel consisting of a radiologist, a cardiologist, an emergency medicine doctor with an interest in POCUS, a sonographer and an echocardiographer reviewed all the available images and undertook a further clinical records review for 403(40%) of the 1014 POCUS cases. Ultrasound is well established in radiology, cardiology and emergency medicine with recognised training and standards. The panel's principal role was to objectively assess the rural POCUS practice in light of these standards. Three hundred and fifteen cases were referred to the panel by the investigators for review because they considered there was some uncertainty about the impact the POCUS may have had on patient management or there was a possibility the POCUS had a negative impact on patient care. In addition panel members reviewed all 18 obstetric or pelvic scans because this type of scan was identified by the panel as being potentially problematic. The remaining 70 cases were a random sample of those not already reviewed by the panel.

Scans of the jugular venous pressure (JVP) and Inferior Vena Cava (IVC) were excluded from several outcomes (scan interpretation, accuracy of POCUS findings and impact on diagnostic probability) either because it was not possible to assess the accuracy or they were not used to establish a diagnosis.

Ethics approval was obtained from the NZ Multi Region Ethics Committee MEC/10/09/091 and in line with this, consent was obtained from the participating doctors.

Statistical analysis was undertaken using SPSS Version 23. Descriptive statistics were used to describe study outcomes. Spearman correlation coefficient was used to establish the correlation between the patients' pre and post-scan disposition and between the post scan and actual disposition.

Results

A description of the study hospitals is summarised in Table 30. A separate paper details and discusses the scope of POCUS (i.e. the range and frequency scan type) being practiced in this study. (83) The same paper also contains additional information on the hospitals, the participants and the characteristics of the patients scanned. All the participants were senior rural generalist doctors who had undertaken formal POCUS training.

Table 30: Characteristics of the study rural hospitals

	North Island Hospitals			South Island Hospitals		
	1	2	3	4	5	6
Bed Numbers[1]	10	15	12	30	10	24
Dist. Base Hospital (km)[2]	126	55	57	112	187	200
Approx. Resident Catchment Pop.[3]	6500	36,500	13500	21000	17500	26000
% Māori in Catchment[4]	74	41	31	4.5	5.4	6

1. Number of general medical inpatient beds
2. Distance to the nearest base hospital by road in km. The base hospital covering Hospitals 1,2,3 and 5 do not have tertiary services such as interventional cardiology or vascular surgery. The tertiary hospitals providing these services is a further 160 to 200km distant.
3. Rural health facilities in NZ do not have clearly defined catchment boundaries. These figures were obtained from local hospital administrators.
4. Māori as a percentage of catchment population.

Over the nine months of the study the 28 participating doctors undertook 1248 POCUS examinations on 1014 cases and from these derived 1409 POCUS findings. Electronic records of images or clips were available for 1014/1248 (81%) of the POCUS examinations.

The most commonly performed examinations were cardiac, gallbladder, kidney, inferior vena cava and FAST (focused assessment with sonography for trauma). (83)

Analyses of the POCUS examinations, cases and findings are presented in Tables 31, 32, and 33 respectively.

Table 31: Analysis of POCUS examinations

Total examinations undertaken		1247
Self Reported Scan Quality[1]:	Missing	156
	Good	379/1091 (36%)
	Adequate	605/1091 (56%)
	Non Diagnostic	89/1091 (8%)
Assessed Scan Quality[2]:	Missing	233
	Good	631/1014 (62%)
	Adequate	217/1014 (21%)
	Inadequate but diagnostic	98/1014 (10%)
	Non diagnostic	68/1014 (7%)
Scan Interpretation[3]:	Missing	298
	Correct	811/949 (85%)
	Partially correct	75/949 (8%)
	Incorrect	63/949 (7%)

1. Participant's assessment of the technical quality of their POCUS images
2. Specialist panels assessment of the technical quality of the POCUS images
3. Accuracy of the participant's interpretation on their POCUS as judged by the specialist panel.

Table 32: Accuracy of POCUS findings

Total CPU Findings	1237
Missing	165
Correct	965/1072 (90%)
Incorrect	107/1072 (10%)

Participants POCUS findings as stated on questionnaire compared to definitive finding derived from results of formal imaging, final diagnosis or review of POCUS images by the specialist panel.

Table 33: Impact of POCUS on disposition and overall patient care

Total POCUS Cases		1014
Patient disposition:	Missing	112
	No Change	796/902 (88%)
	Deescalated[1]	68/902 (8%)
	Escalated[2]	38/902 (4%)
Overall impact on patient care:	Missing	0
	Nil	261/1014 (26%)
	Some	493/1014 (48.6%)
	Significant	226/1014 (22%)
	Major	4/1014 (0.4%)
	Negative	30/1014 (3%)

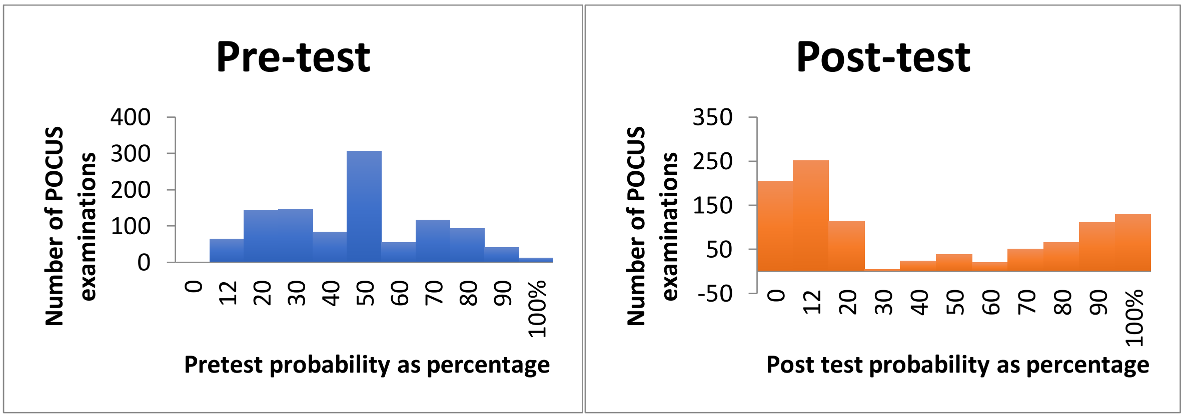
1. Deescalated = Less intensive and less expensive management. E.g. discharge vs. hospital admission, local management vs. transfer to urban hospital, transfer by road vs. by air ambulance.
2. Escalated = More intensive and specialised management. E.g. hospital admission vs. discharge, transfer to urban hospital vs. local management, transfer by air vs. transfer by road.

Scan Quality: Members of the specialist panel were more likely than the participants to judge the quality of images to be good (62% vs. 32 %); but considered a similar proportion of scans to be non diagnostic (8% vs. 7%).

Accuracy of Interpretation and Findings: The two analyses that examined POCUS accuracy produced similar error rates. Ten per cent of the time the participants' POCUS findings were incorrect when compared to definitive findings derived from the patient record. Similarly, when the POCUS images were reviewed by members of the specialist panel, the participants' interpretation was considered to be incorrect for 7% and only partially correct for 8%.

Diagnostic Probability: The impact on diagnostic probability is illustrated in Figure 10. POCUS improved diagnostic certainty for 87% of cases, increasing the doctors' confidence that the principal diagnosis being considered was either correct or incorrect. For the remaining 13% POCUS did not alter diagnostic probability. The mean change between pre- and post-test probability was 28% change (SD=18) in either direction.

Figure 10: Change in probability of diagnoses being considered as a result of POCUS

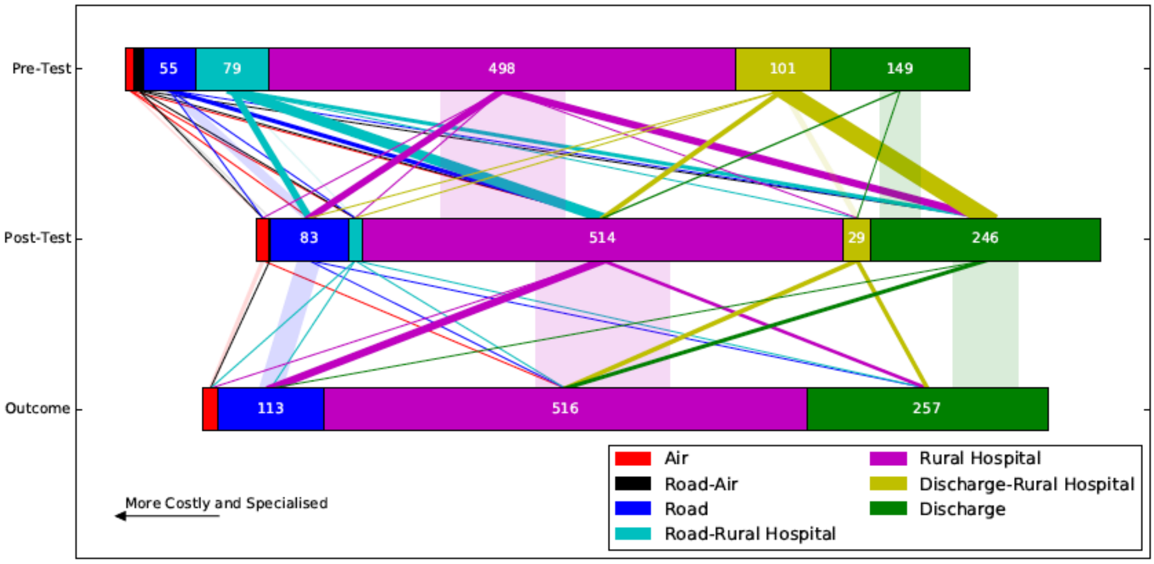


The probability (in the view of the participating doctor) that the important diagnosis they are considering is correct before (pre-test) and after (post-test) they have undertaken the Point-of-care ultrasound examination.

The probability (in the view of the participating doctor) that the important diagnosis they are considering is correct before (pre-test) and after (post-test) they have undertaken the Point of Care Ultrasound examination.

Patient Disposition: Figure 11 tracks the planned disposition of each patient before and after the POCUS and shows the actual disposition. The correlation between the post-scan and the actual dispositions is very strong (Spearman correlation coefficient = 0.89 n=902 $p<0.01$), stronger than the correlation between pre-scan and post-scan dispositions (Spearman correlation coefficient = 0.72 n=902 $p<0.01$). The correlation between pre-test and actual disposition was weakest (Spearman correlation coefficient = 0.66 n=902 $p<0.01$). Taken together these indicate that POCUS altered the planned disposition of patients, moving it closer to what actually occurred. On occasions (8%) POCUS deescalated the level of care; reducing the need for hospital admission and transfer. The care for 4% of patients was escalated by transfer to a specialist base hospital with the potential for improved outcomes.

Figure 11: Impact of point-of-care ultrasound on the planned disposition of patients and the actual patient disposition.



Types of patient disposition:
Air = Number of patients for transfer (actual or planned) to base hospital by air ambulance
Road–Air = Number of patients whom the participating doctor was considering either road or air ambulance to base hospital
Road = Number of patients for transfer (actual or planned) to base hospital by road ambulance
Road-Rural Hospital = Number of patients whom the participating doctor was considering either road transfer to base hospital or admission to local rural hospital
Rural hospital = Number of patients for admission (actual or planned) to local rural hospital
Discharge-Rural Hospital = Number of patients whom the participating doctor was considering either road transfer to base hospital or admission to local rural hospital
Discharge = Number of patients for discharge (actual or planned)

Pre-test = The participating doctor's planned disposition for the patient prior to them undertaken the POCUS examination
Post-test = The participating doctor's planned disposition for the patient subsequent to completing the POCUS examination
Outcome = Actual patient disposition

Movement to the right represents less intensive patient management with the potential for reduced healthcare costs.
Movement to the left represents more intensive and specialised patient management with the potential for improved patient outcomes.

The thickness of the lines between the bars represent the number of patients moving between disposition categories (logarithmic scale).

Overall Impact on Patient Care: POCUS was judged to have had no impact on patient care in 26% of cases but the majority of patients (71%) were judged to have benefited. In 3%

(30/1014) of the cases the specialist panel determined that there was a possibility that the POCUS could have had a negative impact on patient care. For 6 cases POCUS delayed accessing definitive investigation or treatment and in 4 cases an alternative imaging modality should have been used. For 17 cases this was in the form of an incorrect diagnosis as detailed in Table 34. In no case did the panel find definitive evidence that the POCUS had resulted in a serious adverse outcome.

Table 34: POCUS scans with a potentially negative impact due to diagnostic error

No. of examinations	POCUS finding	Definitive finding
2	No gallstones	Gallstones
1	Gallstones	No gallstones
1	Normal kidney	Hydronephrosis
2	Normal kidney	Stones in renal pelvis
1	FAST[1] – no free fluid	FAST[1] – free intraperitoneal fluid
1	Moderately impaired LV[2] function	Severely impaired LV[2] function
1	Normal LV[2] function	Moderately impaired LV[2] function
1	Normal echocardiogram	Aortic stenosis
1	Dilated right heart	Normal echocardiogram
1	Retained products of conception	No retained products
1	Normal pelvis	Hemorrhagic ovarian cyst
1	Ovarian cyst	Normal pelvis
1	No pneumothorax	Pneumothorax
1	Superficial thrombophlebitis	Normal superficial vein
1	Foreign body	No foreign body

1. Focused assessment with sonography in trauma. 2. Left ventricular

Discussion

This study suggests that by increasing diagnostic certainty POCUS is having a positive impact on patient care in rural NZ. At the same time it raises important questions around quality and safety.

Quality and safety: The error rates for POCUS identified in this study are higher than those reported elsewhere, which quote sensitivities and specificities between 96 and 100% for the detection of abdominal aortic aneurysm (AAA) and pericardial effusion. (195, 196) Several factors may be responsible for this. Previous studies were usually conducted in urban academic emergency departments and involved a single POCUS examination. The rural generalists in this real world study were practicing a broad scope of POCUS, including complex examinations such as evaluating left ventricular function, which is technically more difficult than the detection of AAA or a pericardial effusion. They often had few, if any, other imaging options available. The standards expected of the rural doctors in this study were set not by their colleagues, but by the specialist panel who would be accustomed to a different clinical context. The considerable inter-observer variation in interpretation that is known to occur even amongst experienced radiologists should also be taken into account when considering these results. (197, 198) Regardless of these considerations the results of this study highlight the potential risks of POCUS, helping to confirm that it can be a technically difficult set of skills to learn. Careful consideration therefore needs to be given to standards of training, safe scopes of practice and on-going quality assurance, for rural POCUS.

The review of clinical records that was overseen by the specialist panel was more reassuring; demonstrating that POCUS benefited the majority of patients, often significantly. Despite the technical and image interpretation problems that were identified only occasionally was there a possibility that the POCUS compromised patient care and on no occasion was there definitive evidence of an adverse outcome. The participating doctors in this study appeared to be aware of the limitations of their POCUS skills and when appropriate gave more weight to the information gained in the rest of the clinical assessment. A number of characteristics of safe POCUS practice have been identified. These include being focused and goal-directed, with easily recognisable findings using techniques that can be easily learnt. (172, 199) The results of this study reinforce a further feature of safe POCUS practice; the importance of using it as an adjunct to clinical assessment, performed by a clinician involved in the care of the patient. Because POCUS is performed by the clinician, in real time at the bedside, the findings can be clinically interpreted with the patient's symptoms and physical signs. (172, 200) The beneficial patient outcomes observed in this study cannot be generalised to POCUS as a stand-alone, referred or consultative investigation.

The decision to transfer a patient to a distant institution has implications for patients and their families that go beyond the level of clinical care they receive. These are some of the most resource intensive decisions rural doctors routinely make. (74) Even a relatively small overall reduction in inter-hospital transfers, as demonstrated in this study, will result in significant savings for individual patients and the healthcare system.

Limitations: The number of cases scanned without the requested data collected, is unknown. For other patients, data is missing for some variables because the participant failed to complete sections of the questionnaire or to keep electronic records of the images. How much information was collected varied between participating doctors. For example two of the participants were responsible for 22% of the cases in which the information on self-reported scan quality was missing. These 2 doctors undertook only 6% of all scans. One doctor completed this section of the questionnaire only 20% of the time while 18 completed it more than 90% of the time and 10, 100% of the time.

The participants recorded a 'planned' or 'intended' patient disposition, which may have differed from what they would have actually done. The strong correlation between the post-scan disposition and actual disposition suggests that this difference was small. Both of the reviewing investigators are rural generalist doctors who have actively promoted rural POCUS in NZ, increasing the potential for bias. The inclusion of the panel of specialists from other branches of medicine reduced this potential for bias.

This is the first study conducted in the resource-limited context of rural medicine to evaluate the quality and safety of POCUS and its impact on patient care. We have demonstrated that the information obtained by POCUS alters patient management, including reducing hospital admissions and inter-hospital transfers and, when used as an integrated component of a clinical assessment, improves patient outcomes. We have highlighted the challenge of learning and maintaining the skills to safely practice the broad scope of POCUS being practiced by rural doctors. Further research needs to be done to define a safe scope of rural POCUS practice and how to support this with the right training, credentialing and quality assurance programmes.

-End of published manuscript-

Addressing the evaluation framework

Quality: As discussed, quality and safety are important indicators of the *appropriateness* of rural POCUS. In this study, quality was evaluated by auditing image quality and image interpretation and comparing POCUS findings with the results of definitive imaging. A review of the clinical records was undertaken (involving a specialist panel) to judge the impact POCUS had on overall patient care, and to look specifically for any evidence of patient harm as a result of POCUS errors. Although *morbidity* and *mortality* were not measured directly, the quality indicators that were measured suggested that POCUS was not causing harm and was having, overall, a positive impact on patient care. The participating doctors were more likely to make errors when they moved beyond the scope of practice they had been trained in. The commonly-made errors, patterns of errors (e.g. overestimating the diameters of cylindrical structures by cutting them obliquely), and more problematic scan types were identified. This information will usefully inform safe scopes of practice and targeted rural POCUS training.

Effectiveness: Two indicators addressed the *effectiveness* of POCUS: the impact on diagnostic certainty; and the overall impact on patient care. By both measures rural POCUS was an *effective service.*

Efficiency: This study did not quantify the costs of POCUS, which would be significant and would include the cost of training, equipment and clinician time. The study did however address the effect of POCUS on patient disposition (the decision to admit, discharge or transfer a patient), and in doing so identified the area of greatest potential savings as a consequence of POCUS. This is the second study in this thesis to measure the impact on disposition, an important but seldom studied indicator for the *efficiency* of a rural health service.

Wellbeing: Because of the financial costs and social disruption that occurs when a family member is transferred to a distant hospital, avoiding unnecessary transfers has a benefit in terms of patient and community *wellbeing.*

Chapter 10: Rural point-of-care ultrasound of the kidney and bladder

Context statement

The reliability of different ultrasound examinations performed by rural generalist doctors varies, with some examinations proving much easier to perform and interpret. It is not surprising then that the participating doctors identified a recognised scope of practice as a major POCUS safety priority (Ch. 8).

Chapter 10 is the first subgroup analysis of the POCUS study. It applies the methodology used in Chapter 9 to individual scan types, in this case ultrasound of the bladder and kidney. The same study specific questions were addressed: *Are rural doctors obtaining bladder and kidney images of diagnostic quality? How accurately are they interpreting these images? What impact is POCUS of the bladder and kidney having on diagnostic certainty? What impact is POCUS of the kidney and bladder having on discharge and transfer decisions? Is there evidence of patient harm? What is the overall impact of POCUS of the kidney and bladder on patient care?* It was also possible to calculate the sensitivity and specificity of rural POCUS of the bladder and kidney and identify particular quality issues with these techniques. The information gained will help define an appropriate scope of POCUS practice and improve training for rural generalist doctors.

Nixon G, Blattner K, Muirhead J, Kerse N. Rural point-of-care ultrasound of the kidney and bladder: quality and effect on patient management. J Prim Health Care. 2018;10(4):324-30.

Introduction

Point of care ultrasound (POCUS) of the kidney and bladder are the 4th and 6th most commonly performed POCUS examinations by New Zealand rural doctors. (201)

POCUS of the kidney is also commonly performed in emergency departments, a practice that is supported by the emergency medicine literature. (202) The principal finding being sought is hydronephrosis, usually when the differential diagnosis includes renal colic. POCUS of the bladder, as a test for urinary retention, is an even more straightforward examination, frequently performed by nursing and medical staff outside the radiology department. (203)

Those who practice point of care ultrasound in rural New Zealand consider it a valuable additional skill. (83) This is principally because alternative diagnostic imaging is limited in NZ's rural hospitals. Plain x-ray is often available only during normal working hours, few rural hospitals have formal ultrasound (performed by a trained sonographer and reported by a radiologist) and even fewer have immediate access to computed tomography. (31)

POCUS can be a technically difficult skill to learn. This is reflected in the formal training and accreditation processes that have been adopted by emergency medicine colleges around the world. (204, 205) POCUS is also resource intensive, both with respect to equipment and training costs.

Few articles have been published on POCUS in the rural setting and we were unable to find any studies that evaluated the benefits (or otherwise) of POCUS to patient care in the rural context. The aim of this study is to evaluate POCUS of the kidney and bladder, in particular the ability of rural doctors to obtain and correctly interpret ultrasound images, the accuracy of their POCUS findings and the impact on diagnostic decision-making and patient management.

Methods

This study is a subgroup analysis of a larger study examining the safety and impact on patient care of POCUS in rural New Zealand. (206)

Twenty-eight rural generalist doctors, working in six rural NZ hospitals were enrolled in the study over a nine-month period in 2012. Three of the study hospitals were in the North Island and three in the South Island. The characteristics of the participating doctors (including their POCUS training) and the study hospitals, along with detailed methods are reported elsewhere. (83)

The participating doctors completed a questionnaire each time they used POCUS as part of their routine clinical duties. They completed the first section of the questionnaire prior to doing the POCUS examination and the second section after the POCUS (post-test). Both sections recorded 1) the participating doctors' estimation of the likelihood of the major diagnoses being considered (diagnostic probability) and 2) their planned disposition for the patient (i.e. discharge, admission to the local rural hospital or transfer to specialist base hospital by road or air). The differences between pre-test and post-test recordings were used to measure the impact of POCUS on diagnostic decision-making and patient disposition. The questionnaire also included the participating doctors' impression of the image quality (self-reported scan quality) and their interpretation of the images (POCUS findings).

The investigators reviewed the clinical records of all cases in the three months following the study period. Where possible definitive findings were determined based on the results of formal diagnostic imaging, the final diagnosis or a review of the saved POCUS images. Using the information in the clinical record the investigators categorised the impact the POCUS had on the patient management as either nil, some, significant, major or negative. 'Some' impact on patient management included confirming a diagnosis that was likely to have been made without the scan or ruling out an important but very unlikely diagnosis. Examples of 'significant' impacts on management included changing the intended patient disposition (e.g. deciding to discharge a patient that might have otherwise been admitted for observation) or leading to a diagnosis that was unclear prior to the scan. To meet the threshold for 'major' impact there had to be evidence that the POCUS avoided major disability or death. 'Negative' impact was any situation in which it appeared the patient would have been better not to have had the POCUS scan; i.e. it delayed the correct diagnosis or resulted in inappropriate clinical management. A specialist panel (comprising an emergency physician with an interest in POCUS, a radiologist, and a sonographer) undertook a second review of the clinical record for selected cases. The panel reviewed all cases where investigators judged the impact to have been negative and any cases where the investigators were uncertain about the definitive findings or the impact POCUS had on patient care.

When they were available, the recorded POCUS images were reviewed by the sonographer on the specialist panel. The quality of the images was assessed (assessed scan quality) and the sonographer's interpretation of the images compared with the participant's interpretation (scan interpretation).

Ethics approval was obtained from the NZ Multi Region Ethics Committee MEC/10/09/091.

Statistical analysis was undertaken using SPSS Version 23. Descriptive statistics were used to describe outcomes. True and false positive rates were derived by comparing participants' POCUS findings and the definitive findings (gold standard). Sensitivities, specificities and positive and negative likelihood ratios were calculated using MEDCALC. (207) Spearman correlation coefficient was used to establish the correlation between the patients' pre and post-scan disposition and between the post scan and actual disposition.

Results

The participating doctors undertook 138 kidney and 80 bladder scans over the study period. Electronic records of ultrasound images or clips were available for 124 kidney and 73 bladder scans.

Table 35: Point-of-care ultrasound of the bladder and kidney by rural doctors: Image quality, accuracy and impact on patient care.

	Kidney	Bladder
Total examinations undertaken	138	80
Self Reported Scan Quality[1]: Missing	26[a]	7[a]
Good	31/119 (26%)	26/73 (36%)
Adequate	80/119 (67%)	46/73 (63%)
Non Diagnostic	8/119 (6%)	1/73 (1%)[10]
Assessed Scan Quality[2]: Missing	14[b]	19[b]
Good	77/124(62%)	34/51 (67%)
Adequate	32/124 (26%)	13/51 (25%)
Inadequate but diagnostic	9/124 (7%)	4/51 (8%)
Non diagnostic	6/124 (5%)	0 (0%)
Scan Interpretation[3]: Missing	21[c]	19[b]
Correct	101/117 (86%)	49/51 (96%)
Partially correct	5/117 (4%)	2/51[11] (4%)
Incorrect	11/117 (10%)	0 (0%)
POCUS findings vs. definitive findings[4]:	Hydronephrosis	Urinary retention
True positive	26/117	28/76
True negative	84/117	48/76
False positive	4/117[9]	0/76
False negative	3/117	0/76
Sensitivity	0.9 (95% CI 0.74-0.96)	1.0 (95% CI 0.88- 1.0)
Specificity	0.96(95% CI 0.89-0.98)	1.0 (95% CI 0.93-1.0)
Positive likelihood ratio	19.7 (95%CI 7.5-52)	
Negative likelihood ratio	0.11 (95% CI 0.03-.32)	0
Patient disposition[5]: Missing	14[a]	9[a]
No Change	105/124 (85%)	61/71 (86%)
Deescalated[6]	13/124 (10%)	6/71(8%)
Escalated[7]	6/124 (5%)	4/71(6%)
Overall impact on patient care: Missing	0	0
Nil[8]	35/138 (25%)	6/80 (8%)
Some	74/138 (54%)	45/80 (56%)
Significant	26/138 (19%)	29/80 (36%)
Major	0/138 (0%)	0/80 (0%)
Negative	3/138 (2%)	0/80 (0%)

1. Participating doctors' impression of the quality of their POCUS images
2. Quality of POCUS images as judged by sonographer
3. Participating doctors' interpretation of their POCUS images compared to interpretation by sonographer. This analysis included 8 kidney scans that the participant considered 'non diagnostic' (self reported scan quality). The sonographer considered 3 were of good quality, 2 adequate and 1 inadequate but still diagnostic and 2 non diagnostic.
4. Sources of definitive findings were formal US, CT, the recorded residual volume on bladder catheterisation and the final diagnosis recorded in the patient record. These sensitivity, specificity and likelihood ratio calculations are for the most common findings, hydronephrosis and urinary retention. Results for other, less common, findings are included in the text.
5. Disposition = The decision to discharge, admit to rural hospital to transfer to urban base hospital either by road or air
6. Deescalated = Less intensive and less expensive management; e.g. discharge vs. hospital admission, local management vs. transfer to urban hospital, transfer by road vs. by air ambulance.
7. Escalated = More intensive and specialised management; e.g. hospital admission vs. discharge, transfer to urban hospital vs. local management, transfer by air vs. transfer by road
8. Includes non diagnostic scans
9. The errors were all due to the doctors 'over-calling' mildly dilated collecting systems as abnormal. These were ascertained as within normal limits by the sonographer reviewer.
10. Images were available for this case and were considered by the reviewing sonographer to be adequate.
11. Due to the participant incorrectly measuring the bladder volume.

Reasons for missing data: a. participant failed to complete questionnaire. b. images not saved

c. as per b and in an additional 7 cases interpretation not recorded on questionnaire

The results for both kidney and bladder scans are presented in Table 35. The reasons for missing data are detailed in the footnotes to Table 35. On most occasions this was because participants did not complete parts of the questionnaire or record images.

The sonographer on the specialist panel was more likely than the participants themselves to consider the image quality for kidney scans to be ‘good’ (62% vs 26% respectively). Both the sonographer and the participants considered a similar proportion of the kidney scans to be non-diagnostic (5% and 6% respectively) (Table 33). Similar results were obtained for bladder scans.

It was possible to compare the 139 POCUS kidney findings with definitive findings obtained from the clinical records. The calculated sensitivity, specificity and likelihood ratios for hydronephrosis, the most common finding being sought by participants (117/139 findings), is included in Table 35. On four occasions the finding was a renal cyst. Three of these proved to be correct (true positive) but one was a false positive. On 4 occasions participants concluded there was a stone in either the renal pelvis or the ureter. Only two of these were true positives; i.e. for the remaining two cases no stone was noted in the definitive findings. One renal mass was correctly identified.

The accuracy of the most common bladder finding, urinary retention, is presented in Table 33. On two occasions participants reported finding blood clot in the bladder. On one occasion they were correct (true positive) but on the other they were incorrect (false positive).

Diagnostic Probability

POCUS altered the probability of the principal diagnoses being considered for 97% of kidney cases and 86% of bladder cases. The overall impact on diagnostic probability is illustrated in Figures 12 and 13. Having undertaken POCUS the participating doctors were more likely to be confident that the diagnosis being considered was present or absent (high or low probability). POCUS of the bladder was more likely than POCUS of the kidney to result in diagnostic certainty (post-test probability of 0% or 100%).

Figure 12: Participant reported probability that the principal diagnosis they were considering was correct, before and after point-of-care ultrasound

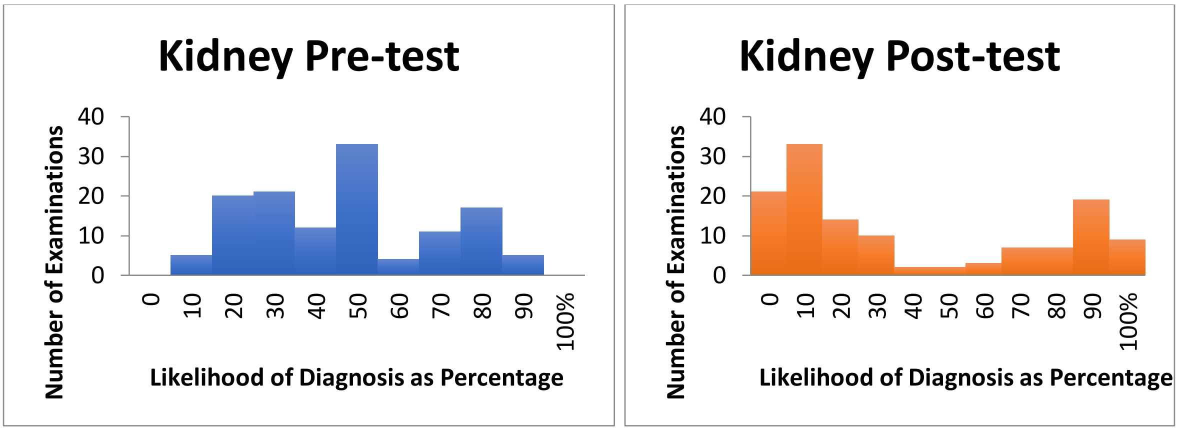
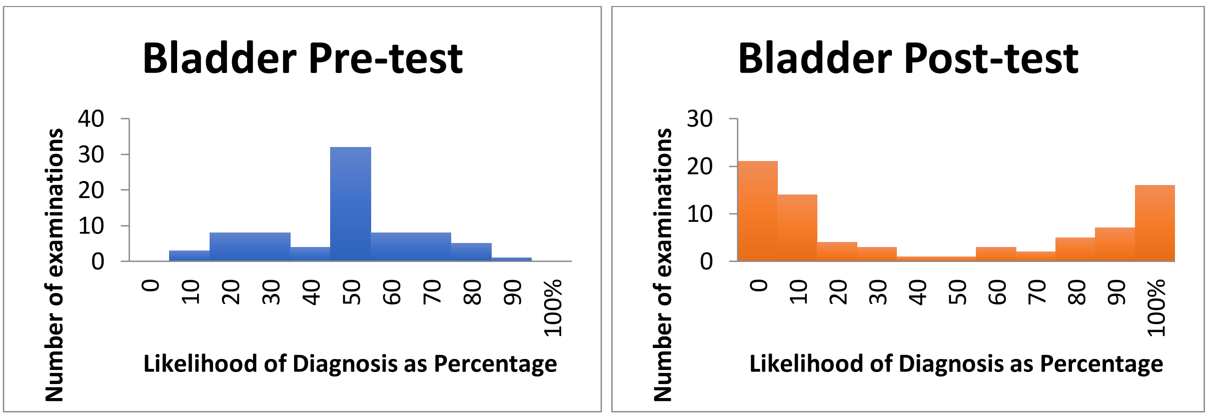


Figure 13: Participant reported probability that the principal diagnosis they were considering was correct, before and after point-of-care ultrasound



Patient Disposition

The impact of POCUS on the planned patient disposition and the actual disposition are illustrated in Figure 3 for kidney scans and Figure 4 for bladder scans.

Figure 14: There was a moderate correlation between pre-test and post-test disposition (Spearman correlation = 0.5 n=124 p<0.01) but a strong correlation between post-test and actual disposition (Spearman = 0.79 n= 124 p<0.01). The correlation between pre-test and actual disposition the weakest 0.49 n= 124 p<0.01.

Figure 15: There was a strong correlation between pre-test and post-test disposition (Spearman correlation = 0.62 n = 71 p<0.01) but very strong correlation between post-test and actual disposition (Spearman = 0.98 n= 71 p< 0.01). The correlation between pre and actual disposition was 0.67 n= 71 p< 0.01.

Figure 14: Impact of point-of-care ultrasound on the planned disposition of patients and the actual patient disposition for kidney scans

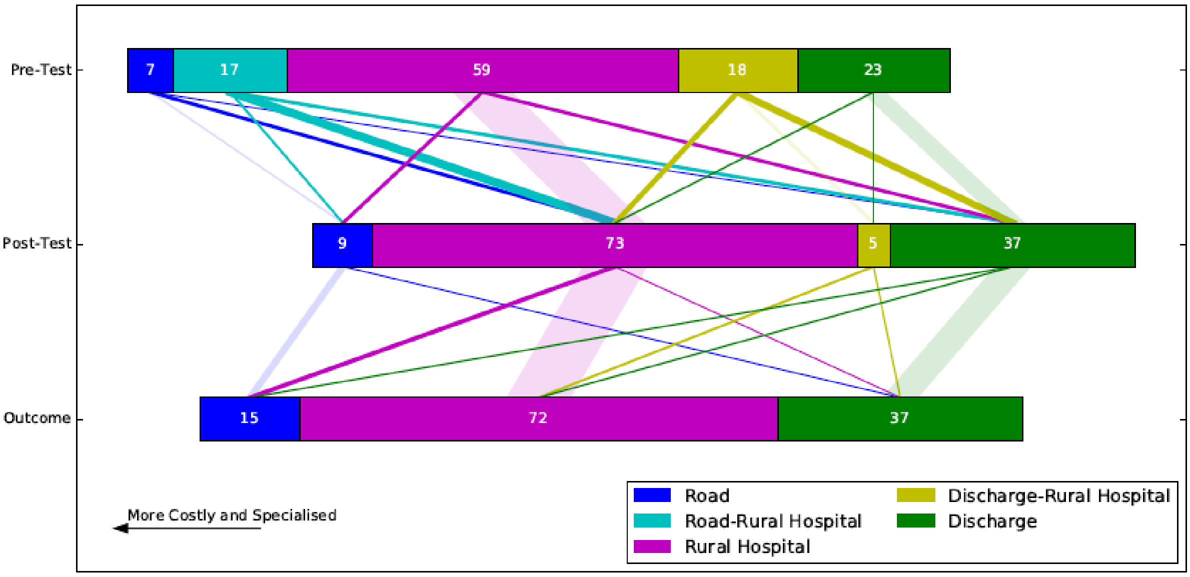
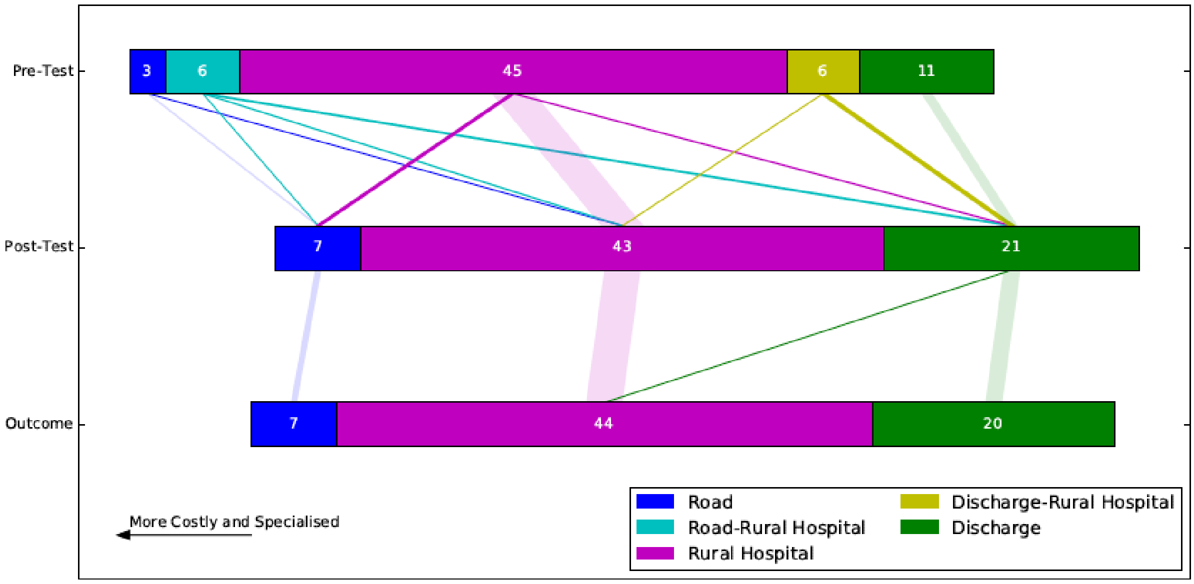


Figure 15: Impact of point-of-care ultrasound on the planned disposition of patients and the actual patient disposition for bladder scans



Legend for Figure 14 and 15
Types of patient disposition:
Road = Number of patients for transfer (actual or planned) to base hospital by road ambulance
Road-Rural Hospital = Number of patients whom the physician was considering either road transfer to base hospital or admission to local rural hospital
Rural hospital = Number of patients for admission (actual or planned) to local rural hospital
Discharge-Rural Hospital = Number of patients whom the physician was considering either road transfer to base hospital or admission to local rural hospital
Discharge = Number of patients for discharge (actual or planned)

Pre-test = The participating doctors' planned disposition for the patient prior to them undertaken the POCUS examination
Post-test = The participating doctors' planned disposition for the patient subsequent to completing the POCUS examination
Outcome = Actual patient disposition

Movement to the right represents less intensive patient management with the potential for reduced healthcare costs. Movement to the left represents more intensive and specialised patient management with the potential for improved patient outcomes.

The thickness of the lines between the bars represent the number of patients moving between disposition categories (logarithmic scale)

The overall impact on patient care is presented in Table 33. On most occasions POCUS was judged to have benefited patient care to at least some degree (73% of kidney scans and 92% of bladder scans). Three cases were identified where POCUS kidney may have negatively impacted on patient care. On one occasion this was the result of missed hydronephrosis. The two other cases were due to missed stones. On no occasion did the specialist panel find definitive evidence of patient harm.

Discussion

This is the first study the authors are aware of that evaluates POCUS of the bladder and kidney in the rural context.

Bladder: In this study POCUS proved to be a highly accurate test for urinary retention (sensitivity & specificity = 100%). This is considerably better than routine physical examination, which has a sensitivity of 80% and specificity of 50%. (208) When taken together these results explain why POCUS frequently increased diagnostic certainty and had a positive impact on patient care without evidence of harm. The low specificity of physical examination supports the authors' impression that a considerable number of patients undergo urinary catheterisation that can be avoided when POCUS is available.

Obtaining and interpreting POCUS images of the bladder for urinary retention was technically straightforward. The only errors identified were with respect to measuring the bladder volume. On two occasions the participants measured bladder depth in the transverse rather than the longitudinal plane. In the transverse plane it is not possible to be sure that the depth is being measured perpendicular to the long axis, which can result in an inaccurate calculated volume. (209) The correct technique for measuring bladder volume should be emphasised when teaching rural doctors POCUS skills.

Kidney: When used as a test for hydronephrosis POCUS proved to be specific (96%) and reasonably sensitive (90%). This sensitivity and specificity are at the upper end of what has been reported in earlier studies on POCUS for hydronephrosis in the emergency medicine literature. (202) The most common error, responsible for all 4 of the false positives, occurred when participants incorrectly interpreted mild dilatation of the collecting system (that was within normal limits) as hydronephrosis. This is particularly likely to occur when POCUS is performed on a patient with a full bladder. The importance of not overcalling mild dilatation of the collecting system and adequately preparing the patient should be reinforced by those teaching rural POCUS.

Hydronephrosis and urinary retention are the two urinary tract POCUS findings routinely taught to rural and emergency medicine doctors. Although numbers are too small to draw firm conclusions, the accuracy of POCUS was poor when the participants sought additional findings such as renal stones or blood clot in the bladder. This study does not provide evidence for the safe practice of rural POCUS of the renal tract beyond the findings of urinary retention and hydronephrosis.

Urinary retention and hydronephrosis are not in themselves findings that would mandate transferring a patient to base hospital; renal colic and urinary retention can often be managed in the rural context. This is in contrast to other POCUS findings such as abdominal aortic aneurysm or free abdominal fluid following blunt abdominal trauma. We therefore did not expect to identify cases in which POCUS had a 'major' impact on patient care. POCUS examinations of the kidney and bladder did however alter planned patient disposition more often than might have been expected (15 and 14 % respectively). As illustrated in Figure 15 and 16 this included both escalating and deescalating the level of patient care. Overall POCUS increased the number of patients who were discharged and saw a similar number of patients transferred to base hospital; suggesting a reduction in health service costs.

In this study POCUS proved to be a useful diagnostic test for patients who may have urinary retention or hydronephrosis in the rural context.

-End of published manuscript-

Addressing the evaluation framework

Quality and safety as indicators of *appropriateness*: POCUS of both the bladder and kidney are reliable tests in the hands of rural doctors when the findings being sought are urinary retention or hydronephrosis, but not for other findings, such as renal stones or clot in the bladder. Common errors were identified. Participants sometimes used the incorrect view to make bladder measurements and interpreted mildly dilated (but still within normal limits) renal collecting systems, as hydronephrosis. These findings reinforce the importance of a defined scope of rural POCUS and the need for emphasising bladder measurement and the interpretation of mild hydronephrosis in rural POCUS training.

Effectiveness: POCUS of the bladder and kidney improved diagnostic certainty and had a positive impact on patient care.

Efficiency: POCUS of the bladder and kidney increase the number of patients that can be discharged and reduces the number of patients needing inter-hospital transfer.

Well-being: Reduced patient transfers has a benefit in terms of patient and community wellbeing.

Chapter 11: Point-of-care ultrasound for the assessment of intravascular volume

Context statement

Chapter 11 is a narrower study, considering the added value of POCUS when assessing a patient’s intravascular volume. POCUS provides a practical alternative to physical examination of the jugular venous pressure (JVP) in the rural context. The study addressed the following questions: *1) what is the image quality of rural POCUS IVC; and 2) do these POCUS techniques generate new and useful clinical information, over and above that obtained by physical examination alone?*

Nixon G, Blattner K, Finnie W, Lawrenson R, Kerse N. Use of point-of-care ultrasound for the assessment of intravascular volume in five rural New Zealand hospitals. Can J Rural Med 2019;24:109-14.

Introduction

An ability to estimate the intravascular volume in patients with heart failure, dehydration or shock is an important skill. Clinical estimation of intravascular volume by physical examination of the jugular venous pressure (JVP) is often inaccurate. (210-212) Estimates of the failure to accurately visualise the JVP by physical examination range from 10 to 80%. (213, 214) The alternative is central venous pressure (CVP) monitoring, which is invasive and impractical in many clinical contexts. Point-of-care ultrasound (POCUS) is now emerging as a further, and practical, option for intravascular volume assessment. (215, 216) POCUS techniques for intravascular volume assessment include i. measuring the diameter and collapsibility of the inferior vena cava (POCUS-IVC) or ii. the height of the JVP (POCUS-JVP). (213, 215)

Studies undertaken in the emergency medicine and specialist outpatient settings suggest that POCUS is more accurate than physical examination. In a study of cardiology clinic patients, the discordance between POCUS-IVC and JVP by physical examination was 32 %, with POCUS proving more accurate. (217) In another study physical examination of the JVP by medical students had a sensitivity of only 13 %, rising to 86% when undertaken by experienced cardiologists, the same sensitivity the medical students achieved with POCUS-IVC after a brief POCUS training session. (211)

Despite being more accurate than physical examination, the ability of POCUS-IVC to predict CVP and fluid responsiveness remains controversial. One systematic review of 21 studies concluded that POCUS-IVC measurement was a ‘valid method of estimating CVP’ and given its ‘ease and safety’ recommended its ‘broader adoption’. (215) A second review, of 17 studies, concluded that respiratory variation of IVC diameter has limited ability to predict fluid responsiveness (pooled sensitivity = 0.63 and specificity =0.73). (216)

The value of POCUS has been more clearly demonstrated in particular clinical situations. POCUS-IVC is a good predictor of fluid responsiveness when the measurements are either very low or very high, (218, 219) when the primary problem is volume loss (dehydration or blood loss) and when it is combined with other POCUS examinations (lung and cardiac). (9) POCUS-IVC has a proven role in heart failure; identifying (in combination POCUS of the lungs and heart) heart failure as the cause of acute breathlessness, (10,11) and as an independent predictor of heart failure prognosis (comparable to brain natriuretic peptide). (220) It is however still unknown if using POCUS-IVC to guide treatment improves outcomes for heart failure patients.

Rural physicians are increasingly incorporating POCUS into their clinical practice and POCUS-IVC & JVP are, collectively, the second most commonly performed examinations by rural generalist physicians in New Zealand (NZ). (83) POCUS does however add to the time it takes to assess a patient and requires an investment in training and equipment. Its role has not previously been examined in the rural context and it is not known how often the experienced rural physician gains additional new useful clinical information by taking the time to perform POCUS-IVC & JVP, and how often they are merely confirming the impression of a patient’s volume they have already obtained by physical examination.

The aim of this study is to determine, i. the quality of interpretation of POCUS-IVC & JVP imaging, ii. the indications for POCUS and iii. the correlation between the findings of physical examination, and the findings of POCUS plus physical examination, for the assessment of intravascular volume, in the rural context.

Methods

This report presents results for the subgroup of POCUS-IVC & JVP examinations undertaken as part of a larger study into the POCUS practice of 28 rural generalist physicians (the participants). All the participants were trained in general practice and/or rural hospital medicine by the Royal NZ College of General Practitioners and were working in six small NZ rural hospitals/health services, ranging in size from 10 to 30 inpatient beds and serving communities with resident populations between 6,500 and 36,000. The study recorded the frequency of scan types undertaken, the quality of the images obtained and the impact on patient management, over a nine month period. This was achieved by asking the participants to complete a questionnaire pre and post-test, and by reviewing the POCUS images and patient clinical records. (83, 221) Results and more detailed methods for the larger study, including the characteristics of the participants and their rural hospitals, are reported elsewhere. (83, 221)

During the study period the participants were encouraged to continue using POCUS as they normally would while undertaking their routine clinical duties. This included choosing when to perform a POCUS-IVC or POCUS-JVP. Prior to undertaking POCUS for volume assessment, the participant recorded on a questionnaire their estimate of the patient's volume based on their physical examination findings, using an 11 point visual analogue scale. The middle of the scale, six, meant that the patient was euvolaemic. The lowest end of the scale – one, indicated the patient was severely hypovolaemic and at the other end -11, severely volume overloaded. After completing the POCUS, the participants re-evaluated the patient's volume and recorded a post-test result using the same scale. The questionnaire also recorded the indication for the POCUS scan and the participant's assessment of the quality of the images they had obtained.

The participants were asked to keep electronic copies of POCUS-IVC images which were reviewed at a later date by a sonographer. POCUS of the JVP involves measuring the height relative to the Angle of Louis, something that cannot be checked with saved images.

Statistical analysis was undertaken using SPSS Version 23. Descriptive statistics were used to describe outcomes. Spearman correlation coefficient and a Bland-Altman plot were used to illustrate the correlation between the physical examination and combined (POCUS and physical examination) findings.

Ethics approval was obtained from the NZ Multi Region Ethics Committee MEC/10/09/091.

Results

Twenty participants in five different rural hospitals undertook 154 POCUS assessments of intravascular volume over the study period. There was considerable variation between the five hospitals in the frequency of POCUS-IVC & JVP scanning (between 5 and 85 scans). (83) No POCUS-IVC or JVP scans were performed in the sixth hospital and by eight of the participants. The median age of the patients scanned was 72 years, ranging from 13 to 98 years. The IVC was scanned in 126 patients, the JVP in 10, and 18 patients had both IVC and JVP scanned.

The indication for POCUS was available for 97% (150/154) of the patients. The most common indications were i. potential dehydration and ii. heart failure (Table 36).

Table 36: Indication[a] for point-of-care ultrasound scan of IVC[b] / JVP[c] by rural physicians

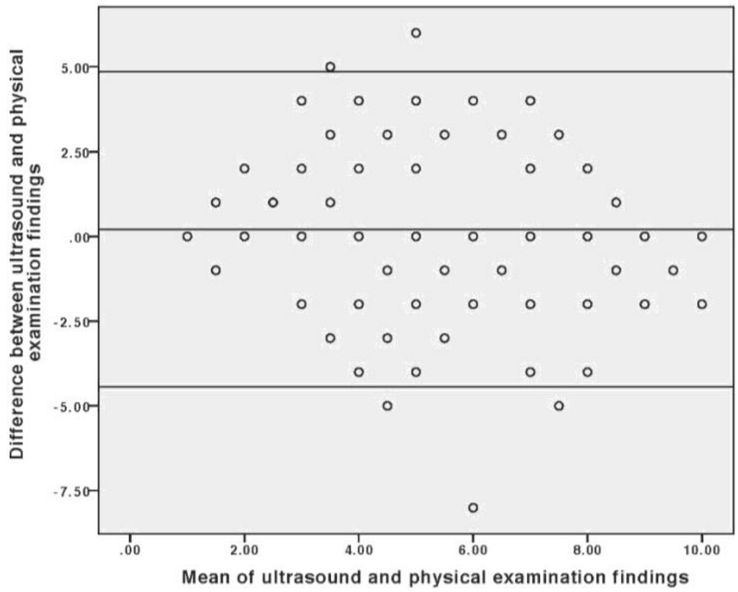
	Number	Per cent
Blood loss	7	5
Undifferentiated collapse	2	1
Heart Failure	55	37
Dehydration	73	48
Renal Failure	3	2
Sepsis	10	7
Total	154	100

[a] Presentation or actual/potential diagnosis
[b] IVC = Inferior Vena Cava
[c] JVP = Jugular Venous Pulse

On 7 (4.8%) out of 144 occasions, participants reported being unable to obtain images of the IVC that were of diagnostic quality. None of the participants reported difficulty in obtaining images of the JVP. Sixty-six IVC images were available for review by the sonographer. This review identified two errors (2/66), in both cases the aorta had been mistaken for the IVC.

The physical examination and POCUS estimations of the patient's volume were recorded on the questionnaire for 97% (150/154) of the patients. The mean difference between the estimation of volume by physical examination and combined POCUS/physical examination was 1.9 (SD 1.45) steps on the visual scale. There was only moderate agreement between the findings as illustrated in the Bland-Altman plot (Figure 16) and by the Spearman correlation coefficient (0.46, n=150, *P* 0.000). Figure 17 illustrates the frequency of the differences between the physical examination and combined POCUS/physical examination findings. For 21% (31/150) there was no difference between the findings, for a further 19% (28/150) the difference was only one on the visual scale and therefore unlikely to be clinically relevant. In 28% (42/150) of cases the difference was four or more points and therefore likely to be clinically significant. In the remaining 32% (49/150) the difference was two or three, which may or may not have been clinically significant. Thirty percent (9/30) of patients who were clinically volume overloaded were hypovolaemic by POCUS and 15% (14/93) of patients who were clinically volume depleted had volume overload on the basis of POCUS.

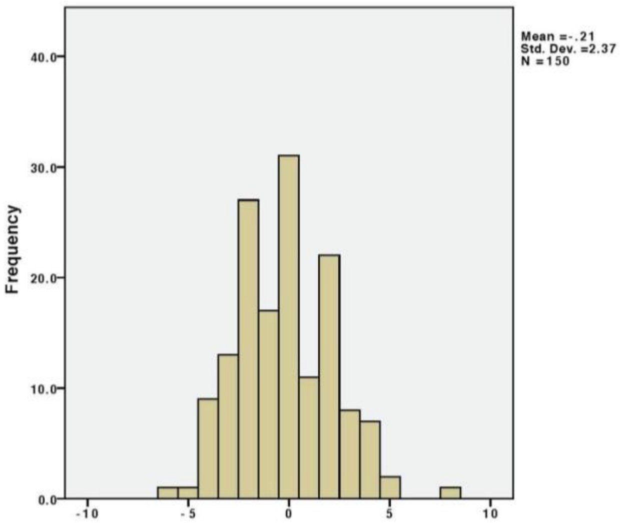
Figure 16: Bland-Altman Plot of correlation between point-of-care ultrasound and physical examination findings for estimation of intravascular volume



x axis – Mean of estimation of patient's volume by 1) physical examination and 2) ultrasound plus physical examination.
y axis - Difference between estimation of patient's volume by 1) physical examination and 2) ultrasound plus physical examination.

Both axes are based on a visual scale of estimated intravascular volume status from 1 to 11. The middle of the scale, 6, meant that the patient was euvolaemic. One indicated the patient was severely hypovolaemic and 11 severely volume overloaded.

Figure 17: Frequency of difference between point-of-care ultrasound findings and physical findings



x axis – Difference between estimation of patient's volume by 1) physical examination and 2) ultrasound plus physical examination. Based on a visual scale of estimated intravascular volume status from 1 to 11. The middle of the scale, 6, meant that the patient was euvolaemic. One indicated the patient was severely hypovolaemic and 11 severely volume overloaded.

Discussion

In this study POCUS frequently altered a physician's impression of a patient's intravascular volume compared to the one they had formed on the basis of physical examination alone. It was not uncommon for a patient judged to be hypovolaemic by physical examination to be considered volume overloaded after POCUS and vice versa. Sometimes the differences were large (Figure 2). On the basis of these results POCUS is providing new clinical information in this context.

Bowel gas in the upper abdomen sometimes obscures the IVC (particularly in unfasted patients), as happened on seven occasions in this study. The two instances identified in this study in which participants mistook the aorta for the IVC are more concerning. This is an avoidable error and one that needs to be noted by those who practice and teach POCUS.

The success rates for obtaining POCUS-JVP images of diagnostic quality in this study (100%) is the same as in other published studies. (222) Because it is such a superficial structure, POCUS-JVP is technically straightforward and easy to learn. (213, 223) The participants chose to perform POCUS-IVC more often than POCUS-JVP. This is likely to be because POCUS of the IVC has a stronger evidence base and, as a more central vein, is likely to be a better predictor of the CVP. (215) POCUS of the IVC may also be more convenient, especially if the patient is already lying flat for a physical or other POCUS examination. POCUS-JVP usually requires the patient to be carefully repositioned.

The results of this study support existing evidence that POCUS-IVC and POCUS-JVP are easily learnt techniques that are more reliable than physical examination. (211, 213, 215, 217)

The real-world nature of this study is a strength. The participants in the study decided when to perform POCUS and which technique to use based on the clinical indications, just as they would in their routine clinical duties. It is likely the patients in this study comprised a group that were particularly hard to assess clinically, chosen because the physician was still uncertain about their volume status after physical examination. The variation between physical examination and POCUS findings in this study is therefore likely to be larger than would be expected if a random or consecutive series of patients had been scanned. The same real-world nature of the study is responsible for its limitations. The numbers are small and it is unknown if participants recorded data for all of the patients they scanned during the study period. Participants also frequently failed to save images of their POCUS scans. The study also did not directly measure whether or not the POCUS findings resulted in a change in clinical management.

The participants in this study were practicing the typically broad scope of rural generalist medicine in New Zealand that traverses primary, secondary and emergency care. This rural generalist scope frequently involves managing acutely unwell undifferentiated patients with limited access to diagnostics, including invasive monitoring. (67) It is not surprising that physicians working in this context will make use of new diagnostic modalities, such as POCUS, that can be practically adopted and resourced in their context. (83)

Further research is needed to determine if POCUS for volume assessment results in improved patient outcomes.

Chapter 12: Point of Care Ultrasound for FAST and AAA in Rural New Zealand

Context statement

Chapter 12 is a further subgroup analysis of the POCUS study, applying the same methodology and study questions used in Chapter 9 and 10 to the subgroup of FAST (focused assessment with sonography in trauma) and AAA (abdominal aortic aneurysm) scan types. This is a further effort to inform a safe scope of rural POCUS practice.

Nixon G, Blattner K, Muirhead J, Kiuru S, Kerse N. Point-of-care ultrasound for FAST and AAA in rural New Zealand: quality and impact on patient care. Rural Remote Health. 2019;19(3):5027.

Introduction

The role of point-of-care ultrasound (POCUS) in assessing patients with suspected abdominal aortic aneurysm (POCUS AAA) and blunt abdominal trauma (FAST = Focused Assessment with Sonography in Trauma) is well established in emergency medicine. These are often the first POCUS examinations urban emergency physicians learn. (224) The potential benefits of POCUS may be even greater in rural settings, (173) where access to imaging modalities, including ultrasound, is generally limited. There are however few published studies to support the use of POCUS in the rural context.

New Zealand's (NZ) dispersed rural communities are served by twenty-six rural hospitals staffed by rural general practitioners and rural hospital generalists. Only two of these hospitals have on site surgical services, few have onsite ultrasound and at the time of this study only 3 had onsite CT. (67) Nineteen percent of NZ's population is reliant on rural health services. (27) When compared to non-Māori NZers, Māori are more likely to live in rural areas and are twice as likely to die as a consequence of abdominal aortic aneurysm (AAA). (25, 225)

Ruptured AAA can be a particularly problematic presentation in rural medicine. Survival falls rapidly the longer the delay to definitive treatment, which can only be provided in a major surgical centre. The symptoms and signs are non-specific and unreliable, resulting in a misdiagnosis rate of 30%. (226) Computed tomography (CT) and formal ultrasound (US) are frequently unavailable in rural areas, particularly outside normal working hours. (31, 67) Rupturing AAA is most often mistaken for renal colic and diverticulitis, both of which are more common than AAA and can often be managed on an outpatient basis or in small rural hospitals. (227) Therefore, a reliable ‘rule out test’ for AAA in the rural context has the potential to reduce the number of patients being transferred to exclude what is an important, but infrequent, diagnosis.

There are close parallels with the use of FAST to assess blunt abdominal trauma (BAT), another common rural presentation. As with AAA, the physical signs are unreliable but the consequences of missing solid organ injury can be potentially serious. Despite its limitations, the assessment of BAT in rural areas is still frequently reliant on careful clinical assessment and serial observation.

The aim of this paper is to evaluate two common POCUS examinations, AAA and FAST in the rural NZ context; in particular the ability of the rural generalist doctors to obtain and correctly interpret images, and the impact of these POCUS examinations on diagnostic decision-making and patient management.

Methods

This study is the subgroup analysis of a larger study that examined the use of POCUS in six geographically dispersed rural hospitals in New Zealand. (83, 221) None of the study hospitals have onsite surgical services. A more detailed description of the methods, study limitations, the characteristics of the participating doctors (including POCUS training), the hospitals and patients scanned, is published elsewhere. (83, 221)

Twenty-eight POCUS active rural generalist doctors were enrolled for a nine-month period during 2012. Each time they undertook POCUS as part of their routine clinical duties they completed a questionnaire both before (pre-test) and after the POCUS (post-test). This recorded 1) the estimated likelihood of the major diagnoses being considered (diagnostic probability) and 2) the planned patient disposition (i.e. discharge, admission to the local rural hospital or transfer to specialist base hospital by road or air). The differences between pre-test and post-test recordings were used to measure the impact of POCUS on diagnostic decision-making and patient disposition. The participating doctors also recorded on the questionnaire their impression of the image quality (self-reported scan quality) and their interpretation of the images (POCUS findings).

The clinical records were reviewed by the investigators and if there was any doubt about the impact the POCUS had on patient management, the case was referred to a specialist panel (comprising an emergency physician with interest in POCUS, a radiologist, and a sonographer). Where possible, definitive findings were determined based on the results of formal diagnostic imaging (CT or ultrasound), the final diagnosis or a review of the saved POCUS images. The impact POCUS had on the patient management was assessed by the investigators and specialist panel as either nil, some, significant, major or negative. 'Some' impact on patient management included, confirming a diagnosis that was likely to have been made without the scan or ruling out an important but very unlikely diagnosis. Examples of 'significant' impacts on management included changing the intended patient disposition (e.g. deciding to discharge a patient that might have otherwise been admitted for observation) or leading to a diagnosis that was unclear prior to the scan. To meet the threshold for 'major' impact there had to be evidence that the POCUS avoided major disability or death. 'Negative' impact was any situation in which it appeared the patient would have been better not to have had the POCUS scan; i.e. it delayed the correct diagnosis or resulted in inappropriate clinical management.

When they were available, the recorded POCUS images were reviewed by the sonographer on the specialist panel. The quality of the images was assessed (assessed scan quality) and the sonographer's interpretation of the images was compared with the participant's interpretation (scan interpretation).

Ethics approval was obtained from the NZ Multi Region Ethics Committee MEC/10/09/091.

Statistical analysis was undertaken using SPSS Version 23. Descriptive statistics were used to describe outcomes. True and false positive rates were derived by comparing participants' POCUS findings and the definitive findings (gold standard). Sensitivities, specificities and positive and negative likelihood ratios were calculated using MEDCALC. (228) Spearman correlation coefficient was used to establish the correlation between the patients' pre and post-scan disposition and between the post-scan and actual disposition.

Results

Sixty-four POCUS AAA scans and 87 FAST scans were undertaken during the study. Study outcomes are presented in Table 37.

Table 37: Study outcomes for rural POCUS[1] AAA and FAST[2] undertaken by rural doctors

		AAA	FAST
Total examinations undertaken		64	87
Self Reported Scan Quality:	Missing	11[a]	10[a]
	Good	17/53 (32%)	35/77 (46%)
	Adequate	29/53 (55%)	40/77 (52%)
	Non Diagnostic	7/53 (13%)	2/77 (2%)
Assessed Scan Quality:	Missing	26[b]	19[b]
	Good	25/38 (66%)	34/68 (50%)
	Adequate	8/38 (21%)	23/68 (34%)
	Inadequate but diagnostic	3/38 (8%)	8/68 (12%)
	Non diagnostic	2/38 (2%)	3/68 (4%)
Scan Interpretation:	Missing	29[c]	22[c]
	Correct	32/35 (91%)	63/65 (97%)
	Partially correct	2/35 (6%)[1]	1/65 (1.5%)
	Incorrect	1/35 (3%)[1]	1/65 (1.5%)
CPU result vs. definitive findings[3]:			
Missing		11[d]	7[e]
True positive		11/53	9/80
True negative		39/53	68/80
False positive		3/53[4]	0/80
False negative		0/53	3/80
Sensitivity		1.0 (95% CI 0.74-1)	0.75 (95% CI 0.47- 0.9)
Specificity		0.93 (95% CI 0.8-0.98)	1.0 (95% CI 0.95-1.0)
Positive likelihood ratio		13.7 (95% CI 4.7-41)	1021(95% CI 0.16-10^6)
Negative likelihood ratio		0.0 (95% CI 0-31)	0.25 (95% CI 0.09-0.7)
Patient disposition[5]:	Missing	5[a]	2[a]
	No Change	50/59 (85%)	68/85 (80%)
	Deescalated[6]	7/59 (12%)	13/85 (15%)
	Escalated[7]	2/59 (3%)	4/85 (5%)
Overall impact on patient care:	Missing	0	0
	Nil[8]	18/64 (28%)	22/87 (25%)
	Some	26/64 (41%)	49/87 (56%)
	Significant	18/64 (28%)	14/87 (16%)
	Major	2/64 (3%)	1/87 (1%)
	Negative	0/64 (0%)	1/87 (1%)

1. POCUS = Point-of Care-Ultrasound. 2. FAST = Focused Assessment with Sonography in Trauma. 3. Sources of definitive findings were formal US, CT and the final diagnosis recorded in the patient record. 4. These errors were all due to the doctors obtaining a falsely elevated aortic diameter by cutting the aorta obliquely. 5. Decision to discharge or admit to local rural hospital or transfer to urban base hospital either by road or air ambulance. 6. Deescalated = Less intensive and less expensive management. E.g. discharge vs. hospital admission, local management vs. transfer to urban hospital, transfer by road vs. by air ambulance. 7. Escalated = More intensive and specialised management. E.g. hospital admission vs. discharge, transfer to urban hospital vs. local management, transfer by air vs. transfer by road. 8. Includes non-diagnostic scans.

Reasons for missing data. a. participant failed to complete questionnaire. b. images not saved. c. as per b and in an additional 3 cases interpretation not recorded on questionnaire. d. 7 scans were of non-diagnostic quality and 4 were likely to be true negatives but it was not possible to confirm this from the clinical record.

Three false positive AAA scans were identified. All three were due to participants bisecting the aorta obliquely in the transverse view and in doing so obtaining a falsely elevated measurement of the diameter.

Three false negative FAST scans were identified. Two were likely due to participant error. In one case, review of the POCUS images demonstrated free fluid that was missed. Although this did not result in an adverse outcome, it did delay the transfer to a city hospital. Because of this delay, this scan was judged by the specialist panel to have had a ‘negative’ impact on the patient’s care (Table 1). In another, while POCUS images were not available for review, the patient had a formal US very soon afterwards that clearly demonstrated free fluid. In the third case, a small amount of free fluid was seen on CT but it is possible this would not have been visible with POCUS. The participant also failed to save images for this case.

Figures 18 and 19 illustrate the impact of POCUS on diagnostic probability. Having undertaken POCUS, the participating doctors were more confident that the diagnosis being considered was present or absent (high or low probability). The diagnoses being considered by the participants were rupturing AAA and solid organ injury from BAT. POCUS AAA was more likely to provide certainty (probability of 0% or 100%) than FAST.

Figure 18: Participant reported probability of ruptured AAA being present after point-of-care ultrasound

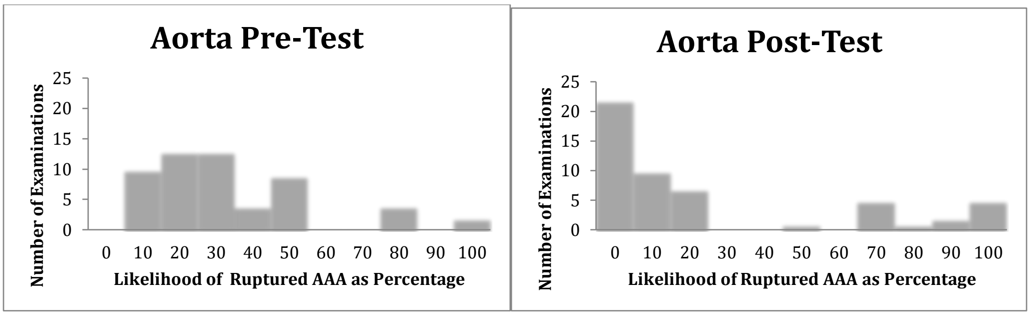
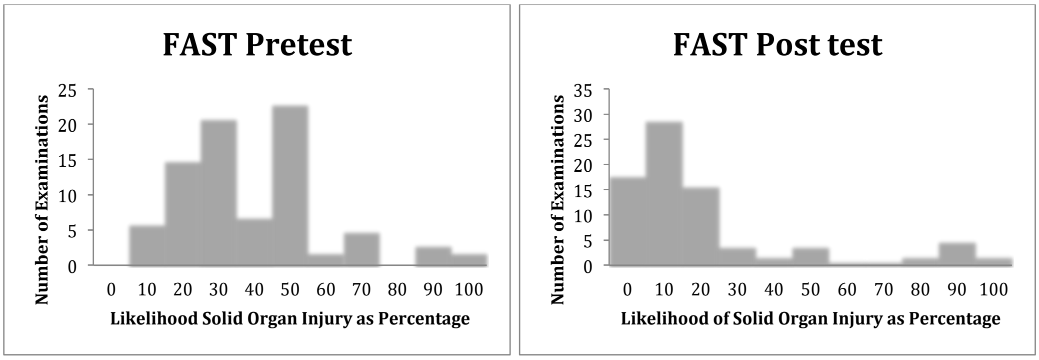


Figure 19: Participant reported probability of solid organ injury being present after point-of-care ultrasound



AAA: For 15% (9/59) of patients, the test altered planned patient disposition as illustrated in Figure 20. There was a strong correlation between pre-test and post-test disposition (Spearman correlation = 0.67, n= 59, $p<0.01$) and a stronger correlation between post-test and actual disposition (Spearman = 0.75 n=57 $p<0.01$). Correlation between pre-test and actual disposition was the poorest (moderate) (Spearman =0.57 n=57 $p<0.01$).

FAST: For 20% (17/85) of patients, the test altered planned patient disposition as illustrated in Figure 22. There was strong correlation between pre-test and post-test disposition (Spearman correlation = 0.67 n=85 $p< 0.01$) and between pre-test and actual disposition

(Spearman disposition 0.68 n= 85 p< 0.01) as well as a very strong correlation between post-test and actual disposition (Spearman = 0.93 n=85 p<0.01).

Figure 20: Impact of point-of-care ultrasound on the planned disposition of patients and the actual patient disposition for AAA scan

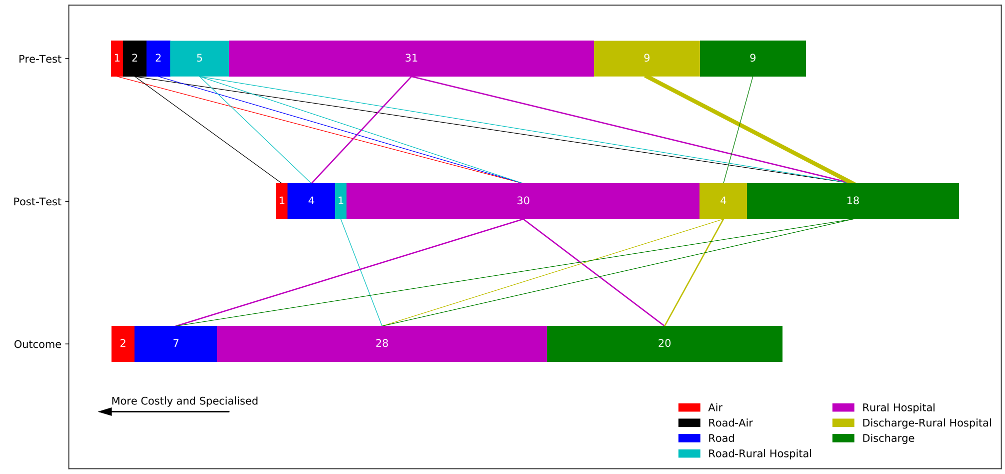
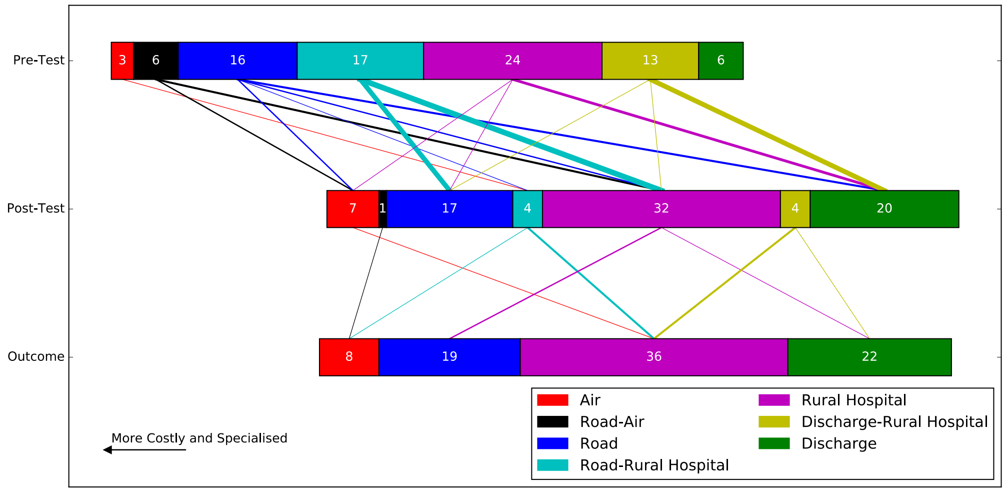


Figure 21: Impact of point-of-care ultrasound on the planned disposition of patients and the actual patient disposition for FAST scans.



Legend for Figure 20 and Figure 21:

Types of patient disposition:
Air = Number of patients for transfer (actual or planned) to base hospital by air ambulance

Road–Air = Number of patients whom the physician was considering either road or air ambulance to base hospital

Road = Number of patients for transfer (actual or planned) to base hospital by road ambulance
Road-Rural Hospital = Number of patients whom the physician was considering either road transfer to base hospital or admission to local rural hospital
Rural hospital = Number of patients for admission (actual or planned) to local rural hospital
Discharge-Rural Hospital = Number of patients whom the physician was considering either road transfer to base hospital or admission to local rural hospital
Discharge = Number of patients for discharge (actual or planned)

Pre-test = The participating doctors' planned disposition for the patient prior to them undertaken the POCUS examination
Post-test = The participating doctors' planned disposition for the patient subsequent to completing the POCUS examination
Outcome = Actual patient disposition

Movement to the right represents less intensive patient management with the potential for reduced healthcare costs.
Movement to the left represents more intensive and specialised patient management with the potential for improved patient outcomes.

The thickness of the lines between the bars represent the number of patients moving between disposition categories (logarithmic scale)

Conclusions

AAA

In this study POCUS AAA by rural generalist doctors was both sensitive (100%) and specific (93%). The participants appeared capable of both obtaining images of diagnostic quality and interpreting them correctly. This is consistent with a systematic review of comparable studies in the emergency medicine literature that quotes a sensitivity of 99% and specificity of 98%. (229)

We can conclude that POCUS AAA is a reliable 'rule out' test for AAA in the rural context. It is therefore not surprising to find that it improved diagnostic certainty and often altered patient disposition; often having a significant (28%) and occasionally a major (3%) benefit on patient care without evidence of patient harm. It is a particularly useful tool in the assessment of older patients with unexplained abdominal pain at a distance from other imaging and surgical care.

It can at times be difficult to find a good sonographic window in the upper abdomen in unfasted patients who are in pain, which could account for the 13% of scans that were non-diagnostic. The false positive rate (6%) could be reduced by an increased emphasis on the importance of measuring the aorta in a true transverse plane by those who teach POCUS to rural doctors.

FAST

By contrast, from the cases examined, FAST was a highly specific (100%) but less sensitive examination (75%) than POCUS AAA. This is consistent with previous larger studies in the emergency medicine literature, which quote sensitivities as low as 42% but specificities of 95%. (230, 231) The loss of sensitivity was due to operator error (participants failed to identify free fluid) and limitations of the technique (inability to detect small amounts of free fluid). These factors have the potential to negatively impact patient care if doctors lack the necessary technical skills or are unaware of the examination's limitations.

Although it did not perform as well as POCUS AAA, FAST frequently improved diagnostic certainty and had a positive impact on patient care. This study reinforces the importance of not using POCUS FAST as a 'rule out' test, (231) something that reduces its utility in the rural setting and needs emphasised by those teaching this technique to rural doctors. However, as a 'rule in' test it can on occasions appropriately escalate the level of care or urgency of transfer with the potential for improved outcomes.

Patient disposition

The decision to transfer a patient to a distant urban hospital by road or air ambulance is a routine part of rural medical practice that has major implications both for the level of care the patient will receive, and resources (costs to both patients and to the healthcare system). In this study POCUS AAA and FAST altered planned disposition for 13% and 18% of patients respectively. The strong and very strong correlation between post-test and actual disposition suggests POCUS is prompting decision making in the direction of appropriate patient management. Overall POCUS reduces the need for hospital admission and inter-hospital transfer, suggesting potential savings to the health care system.

The size of the study and incomplete data are significant limitations of this study. The participants collected the data while undertaking their routine clinical duties in a group of dispersed rural health facilities. This generates useful information on the role of POCUS in the rural context but also created the potential for bias which could have occurred if participants failed to include particular cases, omitted some information, or provided incorrect information on the study questionnaires. The data was also collected in 2012 and POCUS is a rapidly developing field.

This is the first study that we are aware of to examine the impact of FAST and POCUS AAA on acute patient management in the Australasian rural context, and one of the first in any rural context. The results are consistent with larger emergency medicine studies undertaken overseas, namely that POCUS AAA is a good rule out test for AAA and POCUS FAST a good rule in test for solid organ injury.

We have demonstrated that POCUS AAA and FAST increase diagnostic certainty and have a direct impact on patient management, including decisions to discharge or transfer patients, in ways that improve clinical care, increase the number of patients that can be safely discharged and reduce healthcare costs.

The authors recommend POCUS for AAA and FAST should form part of the POCUS scope of practice for rural generalist doctors.

-End of published manuscript-

Addressing the evaluation framework

Quality and safety as indicators of appropriateness: POCUS for FAST and AAA proved to be reliable tests in the hands of rural doctors but with contrasting specificities and sensitivities, meaning POCUS AAA is a reliable 'rule out' (but not 'rule in') test and POCUS FAST a good 'rule in' (not 'rule out') test. This needs to be clearly understood by rural doctors if they are to use these techniques safely. Overestimating the diameter of the aorta by bisecting it obliquely proved to a common error that should be amenable to better training.

Effectiveness: POCUS for FAST and AAA improved diagnostic certainty and had a positive impact on patient care.

Efficiency: POCUS for FAST and AAA increase the number of patients that can be discharged and reduce the number of patients needing inter-hospital transfer.

Wellbeing: Reduced patient transfers has a benefit in terms of patient and community *wellbeing.*

Chapter 13: Conclusion

This concluding chapter starts by briefly outlining the local impacts of the individual studies before moving on to consider the major findings and themes that arise from the body of work as a whole. It then describes what the thesis adds to the existing body of rural health research, the limitations and strengths of the methods used and, finally, the implications for rural health policy.

Local outcomes

The individual studies in this thesis were the result of efforts by the investigators to solve clinical and service problems they were facing in their day-to-day rural practice. The aim was to generate evidence that would help justify investing resources in technology and skills that would fill gaps in the diagnostic services available in their communities. For all intents and purposes, the studies have achieved what they set out to do. All the diagnostic services that were evaluated in these studies are now well-established components of their local rural health service. In some cases, the services have grown in scope and in others they have been adopted by other NZ rural communities. This is not surprising as these were local solutions to local problems, driven by local investigators and clinicians. (232)

The range of point-of-care laboratory testing (POC testing) at Rawene hospital has been extended to include a new stand-alone POC haematology analyser, which we evaluated in a further study. (141) There has been a strong uptake of POC testing across rural NZ, both in rural hospitals and in geographically isolated primary care. In May 2019, we published a survey of POC troponin (Tn) use in NZ rural hospitals. (142) Twenty-two of the 23 hospitals that responded to the survey had access to onsite troponin testing. Of these, 17 used POC Tn assays. In 2018 we published a rural rapid chest pain assessment pathway specifically for use with POC Tn assays. (143)

There are now three computed tomography (CT) scanners operating in rural communities in the Southern District Health Board (SDHB) region where the uptake of rural CT has been much greater than the rest of NZ.

The cardiac exercise testing (ETT) services established at Dunstan and Rawene hospitals have continued. Dunstan Hospital provides a weekly routine clinic and acute inpatient service, with the majority of the tests read by local doctors. The Rawene service continues on a visiting basis. We are aware of two generalist ETT services that have been established in NZ rural hospitals subsequent to the publication of our study: Hawera and Oamaru. Use of point-of-care ultrasound (POCUS) has become ubiquitous in NZ's rural hospitals. There is a portable ultrasound machine in nine of the South Island's 10 rural hospitals, and POCUS training is now routinely undertaken by registrars on the Royal New Zealand College of General Practitioners (RNZCGP) Rural Hospital Medicine Training Programme.

Principal findings

The major findings of the individual studies are organised within the evaluation framework (Table 38: Rural Diagnostic Service Studies; Major Findings and Themes within the Evaluation Framework) to generate a set of overarching findings or themes. Each major finding is then considered in light of the existing literature.

Table 38: Rural diagnostic service studies: Major findings and themes within the evaluation framework

Performance Measure	Principal study findings
Accessibility	**Finding 1: Rural populations have less access to diagnostic investigations than urban populations.** Compared to neighbouring urban communities, those living in rural parts of the SDHB region had much lower CT utilisation rates (Ch.2), and those in rural Northland were much less likely to access ETT (Ch. 7). Queenstown hospital patients with minor head injuries have much lower rates of CT head scans than recommended by national guidelines. (Ch. 4) **Finding 2: Locally-based services can improve access to diagnostic investigations for rural populations.** After introducing a CT scanner in Oamaru, CT utilisation rates increased to be in line with those in nearby urban areas. (Ch.4) ETT utilisation rates increased when a local service was introduced in rural Northland. (Ch. 7)
Appropriateness	**Finding 3: Rural generalists can safely provide some skills-based diagnostic tests that are normally undertaken by urban specialists, but careful consideration needs to be given to training and quality assurance.** Rural generalists with cardiologist back up are able to reliably report ETTS. (Ch.7) The benefits of rural POCUS greatly outweighed the potential for harm. (Ch.9-12) **Error rates with rural POCUS were significant, emphasising the importance of training, quality assurance, and safe, clearly-defined scopes of practice. Errors were moderated when POCUS was incorporated into a full clinical assessment.** 17% of POCUS images were of inadequate quality. (Ch.9) 7% error rate in image interpretation by rural doctors. (Ch.9) 10% error rate when POCUS findings compared to definitive finding. (Ch.9) Considerable variation in the scope of POCUS being practiced by rural doctors. (Ch.8) Some POCUS examinations are much easier to perform than others. (Ch.9-12) Quality assurance in rural POCUS should encompass: 1) defined scopes of practice; 2) recognised training; and 3) initial and ongoing credentialing. (Ch.8,9) The risk for potential harm from POCUS was estimated at 3% (with no actual adverse outcomes identified). (Ch.9)
	Finding 4: Rural diagnostic services better meet the needs of rural Māori

	The Hokianga POC testing service is seen as more culturally appropriate by reducing transfers to base hospital for elderly Māori. (Ch.5,6) This was emphasised again in ETT discussion. (Ch.7) POCUS was shown to also reduce inter-hospital transfers and therefore have similar benefits. (Ch.9,10,12)
Effectiveness	**Finding 5: Rural diagnostic services increase diagnostic certainty.** POC testing reduces the size of the differential diagnosis being considered. (Ch.5) POCUS increases the likelihood that the primary diagnosis being considered is present or absent. (Ch.9,11,12) POCUS of inferior vena cava or jugular venous pulse produced different (and probably more accurate) estimates of intravascular volume than physical examination. (Ch. 11) Greater diagnostic certainty relieves some of the anxiety and burden of rural practice, thereby increasing job satisfaction. (Ch.6,8)
	Finding 6: Rural diagnostic services can improve patient care. POC testing improves communication with base hospital specialists, and facilitates referral and transfers. (Ch.6) Rural ETT service resulted in earlier re-vascularisation procedures for rural patients. (Ch.7) POCUS and POC testing prompted urgent transfer to base hospitals (4% and 5% of patients respectively). (Ch.5,9) POCUS made a positive contribution to patient care for 70% of patients. (Ch.9)
Efficiency	**Finding 7: Rural diagnostic services can be cost effective.** Costs of providing POC testing were more than offset by reduced hospital admissions and inter-hospital transfers. (Ch.5) Unit cost of rural ETT service compares favourably with urban service. (Ch.7) POCUS reduces hospital admissions and inter-hospital transfers. (Ch.9) The rural CT service in Oamaru did not result in over-servicing. (Ch.4)

CT = Computed tomography. SDHB = Southern District Health Board. ETT = Cardiac exercise tolerance testing. POCUS = Point-of-care ultrasound. POC testing = Point-of-care laboratory testing.

Finding 1: Rural populations have less access to diagnostic investigations than urban populations.

Large geographic differences in service utilisation were identified in the CT study (Ch. 2: remote/rural utilisation rate 38% less then urban) and the ETT study (Ch. 7: rural 39% less than urban). Despite the magnitude of these disparities, they had had not previously been recognised by the regions' radiology providers or healthcare planners.

Significant geographic variations in the utilisation of healthcare services unrelated to healthcare need are well described in the international literature, (41, 42) but little effort has been made to describe the differences as they exist between neighbouring rural and urban communities. (6) Diagnostic services, such as those considered in this thesis, have received even less attention. (6, 233)

Both in NZ and overseas, studies about urban-rural differences in access to health services frequently take a provider, or workforce perspective. In a systematic review of rural healthcare shortages published in 2014, (234) 94 of the 176 publications that met the inclusion criteria considered provider shortages. Thirty-three addressed quality issues, again predominantly the expertise of health providers. Few papers considered shortages from a consumer perspective, and the majority of those that were included dealt with distance and the geographic distribution of services. The lack of data on how these workforce and service shortages translate into an urban-rural differential in service utlilisation is surprising, and what data is available is conflicting. (6, 13, 16, 235-239)

The United States (USA) data is the important outlier. In the USA, there is little difference in health service utilisation between rural and urban areas within a given region, although large differences are noted between regions. (235) It is possible that this is a reflection of the way healthcare is funded in the USA, where access to healthcare is synonymous with the individual's health insurance cover. In contrast, this thesis adds the differential utilisation of services within areas funded by the same health funding organisation and relates this to geographic location.

A more consistent picture is obtained when considering other countries with large rural populations and a public health service similar to NZ's, notably Australia, Canada and Scotland, (6, 13, 236, 237, 239), and in some US states with a larger rural hinterland. (238) In these jurisdictions, relative to urban populations:

1. the rural utilisation of primary care services is, overall, slightly lower. (6, 13, 236-240)
2. the rural utilisation of acute and after-hours primary care services is considerably lower. (6, 236)
3. the rural utilisation of specialist services is considerably lower. (6, 236-240)
4. the rural utilisation of emergency departments is considerably higher. (6, 236)
5. the rural rate of hospital admissions is considerably higher. (6, 236, 241) [Paradoxically, hospitalisation rates fall with increasing distance to the nearest hospital. (242)]

These differences need to be interpreted with care because of the different ways urban and rural health services are organised. A defining feature of rural health is the broader scope of practice primary care and generalist practitioners undertake to fill the gaps created by an absence of local specialist services. (240) This should result in a higher utilisation of primary care services, but this is not evident in the statistics, raising the possibility that rural people may be missing out on core primary care services. There is evidence that this is occurring in rural Canada for a range of core primary care services with, for example, lower influenza vaccination rates (237) and primary care screening tests. (13) In 2011, Australia's National

Rural Health Alliance reported on a detailed analysis of rural healthcare utilisation. (236) This report came to similar conclusions; the annual underspend on rural primary care services (Medicare and pharmacy benefits) was between 2.4 and 2.7 billion dollars, assuming rural and urban patients should be using these services at similar rates. This underspend dwarfed the apparent net rural overspend on hospital services of $829 million. (236)

Underinvestment in rural primary care may be partially responsible for higher hospital utilisation for rural populations. (6, 236) This is supported by evidence that the majority of the excess hospitalisations in Australia's rural areas are 'avoidable'. (236, 241) But hospital admission may also be an appropriate response to the rural context. When definitive investigations are less available, admission to hospital for serial observation can be the most appropriate alternative; for example, minor head injuries in Queenstown (Ch.3). Rural hospitals often manage patients that in a city might be admitted to a hospice or a long-term care facility and provide after-hours GP care from their emergency departments. (6, 236) 'Double counting' of hospital admissions can occur if rural residents are transferred from a rural hospital to an urban one as part of a single episode of care. All these factors can raise apparent hospital service utilisation rates for rural populations. Utilisation rates for individual procedures, including the data we presented on CT (Ch, 2,4) and ETT (Ch. 7), may therefore be better indicators of access to secondary and complex care than overall hospital utilisation.

Two studies (Canada and Norway) examining urban vs. rural computed tomography (CT) utilisation were published prior to our NZ study (Ch. 2). Both studies identified large disparities, with rural populations having much lower CT utilisation rates. (89, 243) The Norwegian disparities were of a similar magnitude to those we identified in NZ. (243) The disparities identified in Ontario were smaller, but still significant. (89)

Australian data, based on 2006-2007 Medicare reimbursements, has been published on utilisation of a range of diagnostic services and healthcare procedures, with utilisation rates steadily falling with increasing distance from the nearest metropolitan centre. (236) For example, reimbursement for patients living in remote areas for pathology and radiology services are 23% and 35% lower than expected, based on urban reimbursements. The disparities are even wider for very remote communities. These disparities appear to be increasing over time, not decreasing. (236) Disparities were also identified for elective surgical procedures but these were not nearly as wide, nor as consistent, as those for diagnostic services.

When considered together, our studies and the existing international data, raise the possibility that rural populations face a particular disadvantage in accessing diagnostic services that may be widespread and worsening. This deserves further research, both with respect to the extent and the magnitude of the differential, and to the consequences for health outcomes.

Finding 2: Locally-based services can improve access to diagnostic investigations for rural populations.

An important premise of our studies was that local rural diagnostic services would improve access for those populations. We were able to demonstrate this with respect to rural CT, where the Oamaru CT scanner increased CT utilisation to levels similar to neighbouring urban communities (Ch.4) and, albeit to a lesser extent, with ETT access for the Hokianga community (Ch. 7).

It is accepted that the greater the distance patients have to travel to access a health service, the less likely they are to utilise the service. (242) The corollary is that a local service will result in greater utilisation.

We were able to find only one other study that used rural-urban utilisation rates to demonstrate more equitable access as a consequence of a rural diagnostic service; a Canadian rural CT scanner overcame rural-urban disparities by lifting rural CT utilisation rates to the same level as those in nearby urban areas. (89) This is consistent with the results we obtained for the Oamaru scanner (Ch. 4). We were unable to find studies that used this method to evaluate rural ETT, ultrasound or POC testing services.

Utilisation rates have limitations as an indicator for equitable health service access, which are considered later in this chapter. Quantitative findings on the ability of a local service to improve health service access are considered in the section on implications for rural Māori.

Overall, our findings support what is very likely to be the case, that a rural service provided locally in a rural community will improve access for that community.

Finding 3: Rural generalists can safely provide skills-based diagnostic tests that are normally undertaken by urban specialists, but careful consideration needs to be given to training and quality assurance.

Important issues of quality and safety arise when a skills-based diagnostic test that is normally performed by specialists in an urban centre, is undertaken by generalists in the rural context. This thesis examined rural ETT (Ch. 7) and POCUS services (Ch. 9-12).

In the ETT study, we demonstrated that a rural generalist doctor could accurately report the majority of ETTs, and safely identify those results that would benefit from cardiologist review and reporting (Ch. 7).

We were able to find only one paper that makes a recommendation on ETT supervision and interpretation training for GPs. (169) The recommendation was that 15 supervised tests are adequate preparation for independent practice. The authors acknowledge that there are no published guidelines or evidence to support this number. The results of our study confirming that rural generalists can safely interpret ETTs is, therefore, useful new information.

Quality and safety were particularly important aspects of the POCUS study because of the skills needed to both obtain and accurately interpret ultrasound images. The error rates we identified for rural POCUS were not insignificant and need to be considered by those practising and teaching rural POCUS. When compared to definitive findings (such as imaging by a trained technician with specialist radiology interpretation), POCUS findings were found to be incorrect 10% of the time. Reviews of the recorded images found that about 17% of the time the quality of the images obtained by participants was inadequate, and 7% of the images were incorrectly interpreted. Error rates varied considerably between different POCUS examinations and it was clear that participants used some examinations with more precision and with more accurate interpretation than others. The consistent pattern of POCUS errors that was noted can inform rural POCUS training. The rural generalists in our study appeared to lack the necessary skills to accurately scan the ovaries or to look for ureteric stones, ventricular regional wall or heart valve abnormalities. Table 39 details some of the common errors that could be corrected with better training and an awareness of the problems.

Table 39: POCUS errors commonly made by rural generalist doctors

Scan type	**Error**
Kidney	Mild (normal) dilatation of the collecting system mistaken for hydronephrosis
R ventricle	Overestimation of the size of the R ventricle by cutting it obliquely
Inferior vena cava (IVC)	Mistaking the aorta for the IVC
Gallbladder wall (GB)	Overestimation of the GB wall by cutting it obliquely
Gallstones	Mistaking gas in the proximal small bowel for gallstones
Pericardial effusion	Mistaking left pleural effusion for pericardial fluid
Aorta	Overestimating the diameter of the aorta by cutting it obliquely

There is a large body of POCUS research in the emergency medicine literature. Relevant emergency medicine (ED) guidelines and the research used to generate them, are explored in the discussion sections of each of the POCUS chapters. The majority of ED studies involved teaching emergency physicians or trainees a single POCUS examination and then testing the reliability of their POCUS skills. With respect to individual examinations (for example FAST AAA or hydronephrosis), the reliability of rural POCUS (as measured by sensitivity and specificity) was very similar to those being achieved by emergency physicians (Ch. 10 & 12).

The overall error rates we identified for rural POCUS were higher than those seen for individual scan types in the emergency medicine literature. This can be explained by the broader scope of POCUS examinations undertaken by rural doctors (as identified in Ch. 8), often encompassing more difficult examinations, such as echocardiography.

The absence of alternative imaging in rural areas encourages doctors to push the limits of their POCUS practice and undertake more difficult and complex scans. Emergency physicians in urban hospitals have access to formal imaging on site, such as ultrasound and CT. These are seldom available in rural areas, and the alternative to POCUS is not formal imaging by a trained sonographer or radiologist but routine physical examination. We used the results of formal imaging and the standards set by the urban-based specialists on our expert panel as the 'gold standard' with which to judge the reliability of rural POCUS. However, in many instances, a more appropriate comparison may be routine physical examination. Although POCUS lacks specificity for rupturing AAA and will miss some cases of solid organ injury in blunt abdominal trauma, physical examination is considerably less predictive of these diagnoses (Ch. 12). We compared POCUS with physical examination in only one study (Ch. 12), and noted frequent large differences using the two methods in the estimation of intravascular volume. For this reason, the impact on diagnostic certainty and the overall impact on patient care that were also evaluated in the study (considered under findings 5 and 6), may be better indicators of the true value of rural POCUS than the sensitivity and specificity we measured.

It also needs to be noted that, despite the technical and image interpretation problems that were identified, only rarely (3%) was there a possibility (as judged by the panel) that the POCUS compromised patient care, and on no occasion was there definitive evidence of an adverse outcome. The participating doctors in this study appeared to be aware of the limitations of their POCUS skills and, when clinically appropriate, gave more weight to the information gained in the rest of the clinical assessment. This was an important finding that has implications for POCUS practice. It emphasises the importance of using POCUS as an adjunct to clinical assessment performed by a clinician involved in the care of the patient.

Regardless of any mitigating factors, the broad, variable and technical scope of rural POCUS practice and the error rates we identified (Ch. 8, 9) add weight to the calls made by participating doctors (Ch. 8 survey) for a recognised scope of rural POCUS that is supported by agreed standards of training, credentialing, quality assurance, and opportunities to maintain skills. Chapters 10, 11 and 12 consider particular POCUS scan types and go some way to informing a safe scope of rural practice, but further research needs to be undertaken in this area.

Finding 4: Locally based diagnostic services better meet the needs of rural Māori.

Māori are more likely to live in rural areas than non-Māori, and rural Māori, because of socioeconomic status, face greater barriers travelling to urban-based services (see Introduction).

The qualitative findings in the POC testing study (Ch. 6), and raised again in the ETT study (Ch. 7), highlighted the 'cultural costs' associated with travelling to distant hospitals to access healthcare. This is particularly important for elderly Māori who are concerned about the loss of connection with whānau, whenua and their kaitiaki responsibilities. A common theme in interviews with local providers in the Hokianga (Māori health workers, doctors and nurses) was the unwillingness of elderly patients to travel to the distant base hospital; in fact the sicker they are, the less likely they are to agree to inter-hospital transfer. Despite following a number of potential leads, we were unable to find mention of this in the existing NZ health literature, including a review of the one major NZ government report into the health of rural Māori. (25) The cultural costs borne by unwell, elderly rural Māori when travelling to the city to access healthcare are not adequately appreciated and warrant further research, both to confirm the finding, and to determine impact on health outcomes.

The utilisation and ethnicity data collected in the CT (Ch. 2) and POCUS studies (Ch. 8) add to the body of evidence that Māori do not have equitable access to health services, but also raises the possibility that health services based in rural areas may reduce this inequity. The CT study evaluated urban-based CT services that serviced the entire region (urban and rural areas). The utilisation rate for Māori was 58% of the non-Māori utilisation rates, a large disparity consistent with Māori vs. non-Māori disparities in access to other health services. (244-246)

Although none of the studies were designed to determine whether or not the local nature of the rural health services translated into improved access for local Māori, some of the data from the rural POCUS study suggested that local Māori were receiving equitable access to this service. If the three northern study sites of the rural POCUS study, those with substantial Māori populations, are considered, the proportion of the patients scanned that were Māori was 46%, relative to the proportion of Māori in the catchment populations of 42%. This generates a utilisation rate for Māori that is 1.1 times that of non-Māori. These figures are not age adjusted, and should be considered in light of the much younger age structure of rural Māori populations, (25) the older average age of patients scanned (which would be expected to reduce utilisation of the service by Māori), and the higher disease burden amongst Māori (which should increase the utilisation rate). If taken at face value, these results suggest that local Māori found the POCUS service in rural Northland easy to access. These utilisation rates for rural Māori compare favourably with other published data. The Māori utilisation rate for angiography is 88% of non-Māori, despite a higher disease burden; (245) and Caesarean sections rate for Māori is 68% of the non-Māori rate. (247) Potentially this thesis presents evidence of a reduced disparity in access for Māori when diagnostic services are provided locally in a rural community.

Future research should be undertaken to determine the potential role of rurally-based health services to reduce health inequities for rural Māori by examining health outcomes related to increased access to services.

Diagnostic tests generate ‘intermediate’ results, ultimately of value only if they increase diagnostic certainty, and this, in turn, improves outcomes for patients. The evaluations we undertook demonstrated that the rural diagnostic services were having a positive effect on both these steps: increasing diagnostic certainty (finding 5); and improving subsequent patient care (finding 6).

Finding 5: Rural diagnostic services increase diagnostic certainty.

POC testing and POCUS increased diagnostic certainty by informing the differential diagnosis (Ch. 5,8,10 & 12). POCUS for assessment of intravascular volume frequently provided different (and probably more accurate) findings than those provided by physical examination (Ch. 11). One other small study (McLean 2005) examined the impact of POCUS on diagnostic certainty in the rural context using a similar methodology to ours. (137) The results were similar, with average number of diagnoses on the differential falling from 2.7 pre-test to 1.2 post-test.

The impact of greater diagnostic certainty on patient management (including transfer and discharge decisions) is discussed under findings 6 and 7 below. Before doing this, it is worth considering diagnostic certainty from the point of view of rural practitioners.

There is ample international evidence that rural generalist doctors have a broader scope of practice and less access to specialist testing and consultation than their urban colleagues, (146, 240, 248) and the gap appears to be widening. (240) This thesis supports these findings. Rural doctors in southern NZ were much less likely to refer patients with acute and emergency presentations for a CT and, in doing so, were frequently practising outside national guideline recommendations (Ch. 4).

Previous literature has concentrated on the personality traits of rural doctors and medical students likely to take up rural practice, perhaps seeing high levels of uncertainty as an inevitable part of rural practice and the solution being to produce rural clinicians with a particular 'temperament'. Compared to their urban colleagues, rural doctors and rurally-orientated medical students have a higher tolerance of ambiguity, high levels of resilience, and although they have similar levels of perfectionism, they are less likely to dwell on mistakes. (249)

The issue of how rural doctors respond to the greater diagnostic certainty that results from improved access to diagnostic tests has not been previously explored. We demonstrated that, despite their ability to tolerate ambiguity, the rural doctors in the POC testing study (Ch. 6) responded to the service with a strong sense of relief. Members of the Hokianga medical staff further highlighted this reduction in stress when they published a report on their experience with POC testing entitled 'How to get a good night's sleep in a lab-free zone'. (250) An additional finding was that the test improved communication between the rural doctors and those in urban referral centres, smoothing transfer and referral decisions (Ch. 6). This is because the test results enable the rural doctor to 'speak the same language' as their urban colleagues.

The extent to which local diagnostic services reduced stress and improved job satisfaction for rural practitioners was an unexpected finding. This deserves further exploration, including the possibility raised by these findings; that a greater range of rural diagnostic services might result in improved rural workforce recruitment and retention.

Finding 6: Rural diagnostic services can improve patient care,

An important aim of the POC testing, ETT and POCUS studies was to assess the effect these rural diagnostic services have on patient management. Changes to patient disposition, in particular, indicate a major effect on patient care in the rural context. Some tests frequently altered patient disposition. For example, POCUS AAA and FAST altered planned disposition for 13% and 18% of patients respectively (Ch. 12). POC testing reduced the number of patients needing transfer to a base hospital by 62% (Ch. 5). Changes in patient disposition also have significant social and financial implications for patients (considered under finding 4), and financial implications for the healthcare system (considered under finding 7).

Although both POC testing and POCUS resulted in an overall reduction in inter-hospital transfers and hospital admissions, for a small group of patients the test results prompted urgent transfer to a base hospital (4% of cases in the POC testing study, and 5% in the POCUS study), sometimes by air retrieval. It can be inferred that the urgent transfers occurred because the test identified a previously unrecognised problem that warranted urgent base hospital care, and that this had the potential to improve outcomes.

The POCUS studies evaluated the overall impact of the test on patient care (as judged by an expert panel). In this thesis, POCUS was judged to have had no impact on patient care in

26% of cases but the majority of patients (71%) benefited from the scan. For 22%, the benefit was significant, and for 0.4%, potentially lifesaving (Ch. 9). (For 3% of patients POCUS was judged to have the potential for a negative impact on patient care, although no actual patient harm was identified). A rural POCUS training programme in rural Mexico used log books maintained by the participating doctors to determine the impact of POCUS on patient management. (251) Thirty percent of scans were deemed to have altered patient management, although it is unclear what constituted a change in management. This is the only other study we are aware of on the impact of POCUS, POC testing or ETT on patient management in the rural setting.

POCUS studies in the emergency medicine literature have focused on the sensitivity and specificity of the test relative to formal or expert imaging, and have not gone the next step of measuring the impact on overall patient care. Diagnostic testing can be expensive with considerable opportunity costs to rural health services, and an attempt needs to be made to determine the relative value in terms of improved patient outcomes.

We have demonstrated that POCUS can improve patient care in the rural context. Future research should also consider this context. The utility of POCUS in an urban emergency department environment is not the same as it is in a rural hospital. The utility of POCUS is likely to be far greater when the nearest formal ultrasound or CT is many miles away. Equally, the utility of POC testing will be different in an institution that has no onsite medical laboratory.

Finding 7: Rural diagnostic services can be cost effective.

The ability of economies of scale to contain costs is often used to justify centralising health services in urban centres. Economic evaluation is therefore an important component of rural healthcare service evaluation. This thesis considered the cost effectiveness of the diagnostic services being evaluated in a number of different ways.

Simple economic evaluations (cost minimisation analyses) were undertaken in the POC testing (Ch. 2) and the ETT (Ch. 7) studies. In the POC testing study, savings, in the form of reduced inter-hospital transfers and hospital admissions, far outweighed the costs of the service (equipment, training and staff time). In the ETT study, the costs of providing the rural service compared favourably to the costs of providing the same service in an urban area. The limitations of simple minimisation analyses are considered under Strengths and Limitations.

Although the CT and POCUS studies did not include economic evaluations, they provided evidence of potential savings, or at least cost neutrality, to the healthcare system. The POCUS study (Ch. 9,10,12) identified an overall shift towards less intensive management (increase in the number of patients discharged and reduction in the number of patients transferred to base hospital).

A further reason sometimes raised for not giving generalist doctors (both rural and urban) direct access to complex diagnostic testing is that it will result in inappropriate over referral. These are valid concerns. Large geographic variation in the utilisation of healthcare uncoupled to health need is known to occur when services become freely and locally available. (41, 42) Two of the studies in this thesis looked for evidence of over servicing as a consequence of the local rural service: the Oamaru rural scanner (Ch. 4), and the northern arm of the ETT study (Ch. 7). These studies compared before and after urban and rural utilisation rates, and in neither study did we identify any evidence of rural over servicing.

Despite demonstrating significant overall savings to the health service, both the ETT and the POC testing services may still appear unaffordable. This is because the cost and benefits are apparent to different (and siloed) payers within the health system. In this case, the costs of local diagnostic services fall to the rural health provider, but the savings (in terms of reduced inter-hospital transfers, specialist referrals and base hospital testing) fall to the DHB and ambulance service. This is a frequent problem for rural health providers that are more generalist and integrated and do not fit neatly into the funding silos that are based on urban (primary vs. secondary) models of healthcare delivery. The effect is accentuated for both Central Otago Health Services and Hauora Hokianga (where the studies were centred), because both of these health services are owned and governed by their local community rather than by the local DHB.

Qualitative findings in the POC testing study (Ch. 6) and discussions in the other papers, highlighted the cost shifting from the health system to the patient that occurs when patients have to travel to distant urban centres to access care. These findings include the cultural costs faced by rural Māori when they leave whānau and whenua (finding 4).

The ability of the local diagnostic tests to reduce costs for both patients and the overall health services, particularly by reducing inter-hospital transfers, forms important new findings. It is acknowledged that none of the studies involved more in-depth economic evaluations (such as cost utility analyses) that have the capacity to quantify costs and benefits, including the cultural costs. These types of evaluation need to be considered in future studies of rural diagnostic services.

Strengths and limitations

Methodology

The studies in this thesis employed a common set of pragmatic methods, which can be summarised as follows:

1. Changes in utilisation rates were used to quantify the improvements in access that occurred as a result of the introduction of the rural service.
2. The impact on clinical care (diagnostic certainty and patient disposition) was evaluated by asking the doctor to complete a questionnaire before and after the test and used to reflect the test utility.
3. Urban-based specialists were asked to make a judgement on issues of quality, safety and the overall impact on patient care, reflecting both utility and quality.
4. Qualitative interviews of providers were used to highlight the benefits and challenges of the service.
5. Economic evaluations were undertaken using cost minimisation analyses.

Utilisation rates

As discussed earlier, although utilisation rates are easily measured, they are seldom used as an indicator of access for rural health services. This may be because equitable access and utilisation are not synonymous. Access involves the right patient receiving the right service at the right time (need must also be considered) and it cannot be assumed that rural populations are disadvantaged by lower health service utilisation rates. (252)

It is possible, for example, that the CT utilisation in rural areas (Ch. 2,4) is closer to the optimal rate and that the higher urban rates reflect unnecessary over servicing (particularly on the part of urban emergency departments). These possibilities are behind the frequently heard criticism (including from manuscript reviewers), that the studies in this thesis were not designed to demonstrate improved patient outcomes as evidenced by reductions in mortality and morbidity. This would, however, have been a much more difficult task.

In order to have the power to demonstrate differences in mortality or morbidity, modern studies often need to enroll large numbers of patients. A feature of rural clinical practice is low volumes of any particular presentation, and a parallel problem for rural research is the same low numbers. It is easier with these low numbers to power a study that uses comparisons with an urban service as the primary outcome; for example, comparing health service utilisation rates with those of a nearby urban population as was done in the CT and ETT studies (Ch. 2,4,7). This approach is consistent with the Reeve evaluation framework that recognises equity as an outcome performance measure (along with the traditional outcomes of morbidity and mortality). (71) It could be argued that it is the job of urban-based researchers, with their greater resources and larger study populations, to determine optimum utilisation for a diagnostic service, and the job of rural researchers to demonstrate that rural patients are receiving equitable access.

Self-reported changes in diagnostic certainty and patient disposition.

The pre-test and post-test questionnaires used in the POC testing and POCUS studies to evaluate the effect on diagnostic reasoning and patient management were adapted from ultrasound studies by McLean and Lyon. (136, 137) We have not seen this design used in other rural health studies despite being well suited to the rural context.

This is a pragmatic design that permitted the study questions to be addressed whilst avoiding the significant ethical and logistical requirements of a trial. The obvious criticism is that it is open to bias because of the reliance on self-reported 'intentions' (which may have differed from what the participant would have actually done). For example, in an effort to demonstrate the value of the test, the participant may have overestimated the impact the test had on narrowing the differential diagnosis or on the decision to transfer a patient.

Corroborating evidence was provided in two of the studies that suggests this effect was small. In the POC testing study (Ch. 5), data was available on the numbers of inter-hospital transfers prior to and after the introduction of the service. The observed drop in inter-hospital transfers was in line with the 'intended' disposition data provided by the participants. In the POCUS study, 'actual' disposition data was collected. This correlated closely with the post-test intended dispositions but not those of the pre-test (Ch.9). This data again suggests that the intended dispositions provided by the participants were a true reflection of what they would actually do in the circumstances.

This study design has particular value for rural health researchers because it can be readily implemented in their context. The potential for bias in self-reporting is acknowledged, and a validation study of this methodology would be a useful exercise. This might involve presenting theoretical cases to a group of rural doctors, some of which included POCUS results and some not, and asking them to determine the appropriate patient disposition. The participants would be unaware that the variable of interest was the POCUS result.

When evaluating diagnostic certainty participants were asked to consider each of the important differentials in the diagnosis in isolation. For reasons of simplicity and transparency these were also analysed individually. Diagnostic certainty is complex and involves the certainty of a definitive diagnosis and the certainty of excluding a diagnosis in the context of the whole clinical encounter. More complex statistical analyses that are beyond the scope of this thesis could be used to reflect this, for example structural equation modelling or multistate analyses

Missing data

The 'real world' nature of these studies conducted in day-to-day rural practice is an important strength. It increases the studies' relevance and the likely uptake of the results by rural health services and clinicians.

One of the problems of conducting the research in a less controlled environment was the failure of the participating clinicians to include all relevant cases and provide complete data. This was less of an issue in the POC testing and ETT studies as it was possible to tell when the machines were used and therefore all cases were included.

Missing data is a limitation in the POCUS study. It is possible that some cases (that should have been included) were missed altogether, and we frequently had incomplete data when participants failed to complete pre- or post-test questionnaires. This may have skewed results if particular types of scans were over represented in this group. Fortunately, it appeared that the missing data can be attributed to individual participants, and less so to particular scan types. This is discussed in more detail in Chapter 9.

Multiple methods

The mix of qualitative and quantitative methodologies used in these studies is a strength. A formal qualitative analysis of interviews with stakeholders was undertaken as part of the POC testing study, and the participants were surveyed in the POCUS study. This permitted the benefits (in terms of utilisation or reduced transfers or cost savings) to be measured and at the same time the challenges of delivering the service and the less tangible benefits to be explored in more depth.

The largest of the studies, the POCUS study, involved a complex set of overlapping methodologies. These are described in Table 1, Chapter 9. Although this risked confusing those who would eventually read the results, triangulation improved the validity of the results. For example, the error rates obtained by a review of the POCUS images were very similar to the error rates obtained by comparing the participants' POCUS findings to definitive findings (the results of formal imaging, final diagnosis etc.).

Cost minimisation analysis

Although cost minimisation analyses were simple to perform, they assume that the outcomes of the services being compared are similar and therefore comparable. This is usually not the case. For example, transferring an acutely unwell patient to a base hospital is a very different course of action to obtaining a POC test result and managing the patient locally, and could result in different patient outcomes for many reasons. The benefits of establishing an ETT service in a community with a high cardiovascular disease burden and (and previously poor access to ETT) would be considerably greater than increasing access for an already well-served urban population. This could be overcome by undertaking more in-depth economic analyses (such as cost utility analyses). These are, however, much more complex and resource intensive.

Generalisability

NZ's rural communities are diverse with respect to geography, ethnicity and socioeconomic status. The studies in this thesis were small and confined to a few communities and health services (between one and six). They were also undertaken with limited funding (between $40,000 and $100,000 or, in the case of the study in Chapter 3, with no external funding). Larger studies involving more centres across rural NZ would generate findings that could be generalised more widely and would likely aid in the wider implementation of the results.

At the same time, an effort was made to ensure the results could be generalised as far as possible. Three of the four studies that form the body of this thesis were the result of a collaboration between two community-owned health services at either end of the country, Hauora Hokianga/Hokianga Health Enterprise Trust (HHET) in Northland, and Central Otago Health Services Ltd (COHSL) in the south. The diversity represented by this partnership is considered in the introduction and strengthens the relevance of the findings to all of NZ's rural communities and health services. In the largest of the studies (POCUS), four additional rural sites were included, further strengthening the generalisability of the results.

Improved health outcomes

The results of diagnostic tests are the first and sometimes necessary step in accessing definitive treatment and may have an important role in ensuring rural patients have equitable access to the entire healthcare system.

But it is not possible to determine from existing evidence or the studies we have undertaken, the extent to which poor access to health services is a determinant of the health status of rural NZers. It is safe to say that improved access to services will go some way to improving rural health outcomes, but 'to what extent'? This remains an important issue for ongoing rural health research and planning. (6)

Implications for health policy

1. Health Data and the Rural-Urban Typologies

A paucity of data is routinely collected and published on the health of rural populations in NZ, and the data that has been published is conflicting. This is due, at least in part, to the confusing array of urban-rural typologies that are used to analyse NZ's health data.

A much clearer picture of the true state of the health of rural NZers would be obtained if data were routinely collected on rural vs. urban differences in health outcomes and access to services (in the same way that data are already collected to compare District Health Board regions).

The NZ Health Research Council has recently agreed to fund a project to develop a ‘fit for purpose’ urban-rural typology for health research and policy in NZ. This is a necessary step towards generating meaningful rural health data.

2. Diagnostic services in rural communities

Rurally-based and point-of-care diagnostic services have the potential to improve access to health services and improve clinical care for rural populations, as well as support rural health professionals in their day-to-day practice.

The wider adoption of rural CT, POCUS, POC testing and ETT, has the potential to achieve these goals in a cost-effective manner.

A strategic approach, including ongoing research, could result in an earlier and more consistent adoption of diagnostic services in rural areas, taking advantage of new technologies as they evolve, and reducing the barriers to the uptake of services that result from urban-based funding silos.

3. Quality assurance in rural skills-based diagnostic testing

Rural generalist clinicians can improve diagnostic certainty and reduce inter-hospital transfers when they undertake diagnostic testing such as POCUS, although developing and maintaining the necessary skills can be challenging.

Professional bodies (by setting standards and defining safe scopes of practice), tertiary institutions (by developing robust initial and ongoing training programmes), and rural health services (by putting in place credentialing and quality assurance) all have a role in ensuring rural generalist clinicians can confidently and safely undertake skills-based diagnostic testing.

4. Rural health research and policy

Delivering equitable health care to rural populations demands solutions that are specific to the rural context. In order to achieve this dedicated rural health academic and policy units should be established in our tertiary institutions, the Ministry of Health and district health boards.

5. Rural Māori

Rural Māori may be particularly vulnerable to the impacts of having to travel to access healthcare, and may have the most to gain from the provision of as many health services (including diagnostic tests) as possible in their local communities.

1. New Zealand Institute of Economic Research. Exports of the tech sector compared to other major sectors in New Zealand. Year to June 2015. Accessed April 2019. https://figure.nz/chart/YWDqAS9HH3WixNbs
2. Carter KN, Blakely T, Soeberg M. Trends in survival and life expectancy by ethnicity, income and smoking in New Zealand: 1980s to 2000s. N Z Med J. 2010;123(1320):13-24.
3. Hill S, Sarfati D, Blakely T, Robson B, Purdie G, Chen J, et al. Survival disparities in Indigenous and non-Indigenous New Zealanders with colon cancer: the role of patient comorbidity, treatment and health service factors. J Epidemiol Community Health. 2010;64(2):117-23.
4. Marmot MG. Understanding social inequalities in health. Perspect Biol Med. 2003;46(3 Suppl):S9-23.
5. Cassells K, Reuben D. Specilisation, Subspecialisation and Subsubspecialisation in Internal Medicine. New England Journal of Medicine. 2011;364:1169-73.
6. Pong RW, DesMeules M, Heng D, al. e. Patterns of health service utilization in rural Canada. Chronic Disease and Injuries in Canada. 2011;31:1-36.
7. Pashen, D., Murray, R., Chater, B., Sheedy, V., White, C., Eriksson, L., De La Rue, S., Du Rietz, M. The Expanding Role of the Rural Generalist in Australia – A Systematic Review. Australian College of Rural and Remote Medicine, Brisbane 2007
8. WONCA Executive. WONCA Rural Working Party. The Delhi Declaration: Alma Ata revisited. 15th WONCA Rural Health Conference New Delhi 2018.
9. Eberhardt M, Pamuk E. The importance of place of residence: examining health in rural and non-rural areas. American Journal of Public Health. 2004;94(10):4.
10. Romanow R. Rural and remote communities. In: Building on values: the future of health care in Canada - final report. Saskatoon: Commission on the Future of Health Care in Canada; 2002. p159–69.
11. Australian Institute of Health and Welfare. Australia's health 2016. Rural and Remote Health. https://www.aihw.gov.au/getmedia/6d6c9331-5abf-49ca-827b-e1df177ab0d3/ah16-5-11-rural-remote-health.pdf.aspx
12. Australian Institute of Health and Welfare. Australia's health 2018 (Australia's health series no. 16; Cat. No.AUS 221). Canberra: AIHW; 2018. https://www.aihw.gov.au/reports/australias-health/australiashealth-2018/contents/table-of-contents (viewed June 2019).
13. DesMeules M, Pong R. How Healthy Are Rural Canadians? An asssesment of their health status and health determinents. Ottawa, Canada: Canadian Institute for Health Development; 2006.
14. Rural Health Standing Committee. National Strategic Framework for Rural and Remote Health. Commonwealth Government of Australia. Canberra. Nov. 2011
15. Wakerman J, Humphreys JS. "Better health in the bush": why we urgently need a national rural and remote health strategy. Med J Aust. 2019;210(5):202-3 e1.
16. Smith KB, Humphreys JS, Wilson MG. Addressing the health disadvantage of rural populations: how does epidemiological evidence inform rural health policies and research? Aust J Rural Health. 2008;16(2):56-66.
17. The National Health Committee 'Rural Health, challenges of distance, opportunities for innovation' report. Wellington, New Zealand. 2010.
18. Salmond C, Crampton P, Atkinson J. NZDep2006 Index of Deprivation. Wellington, New Zealand: University of Otago; 2007.
19. https://unstats.un.org/unsd/demographic/sconcerns/densurb/densurbmethods.htm
20. Ministry of Health. Urban–Rural Health Comparisons: Key results of the 2002/03 New Zealand Health Survey. 2007. Ministry of Health: Wellington.
21. StatsNZ. New Zealand: An Urban/Rural Profile (experimental). Christchurch. New Zealand.2003 [Available from: http://archive.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/urban-rural-profile.aspx.
22. Proposed urban influence classification. Functional urban areas. . . Christchurch. New Zealand: Statistics New Zealand; 2019.

23. Lawrenson R, Reid J, Nixon G, Laurenson A. The New Zealand Rural Hospital Doctors Workforce Survey 2015. N Z Med J. 2016;129(1434):9-16.
24. NZ S. Independent urban areas. People. : Statistics NZ.; [Available from: http://archive.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/urban-rural-profile/independent-urban-areas/people.aspx.
25. 2012. MoH. Mātātuhi Tuawhenua:Health of Rural Māori. Wellington. Ministry of Health. 2012. 2012.
26. The ebbing of the human tide. What will it mean? . Wellington: The Institute for Governance and Policy Studies, School of Government at Victoria University of Wellington. Policy Quarterly. ; 2017.
27. Fearnley D, Lawrenson R, Nixon G. 'Poorly defined': unknown unknowns in New Zealand Rural Health. NZMJ. 2016;129(1439):4.
28. Rural Health Indicators. New Zealand Institute of Rural Health. Cambridge. New Zealand.2011 [Available from: http://www.nzirh.org.nz/rural-health-indicators/.
29. Cameron VA, Faatoese AF, Gillies MW, Robertson PJ, Huria TM, Doughty RN, et al. A cohort study comparing cardiovascular risk factors in rural Māori, urban Māori and non-Māori communities in New Zealand. BMJ Open. 2012;2(3).
30. Lawrenson R, Lao C, Elwood M, Brown C, Sarfati D, Campbell I. Urban Rural Differences in Breast Cancer in New Zealand. Int J Environ Res Public Health. 2016;13(10).
31. Nixon G, Samaranayaka A, de Graaf B, McKechnie R, Blattner K, Dovey S. Geographic disparities in the utilisation of computed tomography scanning services in southern New Zealand. Health Policy. 2014;118(2):222-8.
32. Blatter K, Nixon G, Horgan C, Coutts J, Rogers M, Wong B, et al. Evaluation of a rural primary-referred cardiac exercise tolerance test service. NZ Med J. 2014;127(1406).
33. Kent M, A V, Wilkinson T, Poole P. Keeping them interested: a national study of factors that change medical student interest in working rurally. Rural and Remote Health. 2018;18(4872).
34. Zealand. MCoN. The New Zealand Medical Workforce in 2013 and 2014. Wellington: Medical Council of New Zealand; 2016.
35. Crampton P, Jatrana S, Lay-Yee R, Davis P. Exposure to primary medical care in New Zealand: number and duration of general practitioner visits. The New Zealand medical journal [Internet]. 2007 2007; 120(1256):[U2582 p.]. Available from: http://europepmc.org/abstract/MED/17589550.
36. Dowell AC, Hamilton S, McLeod DK. Job satisfaction, psychological morbidity and job stress among New Zealand general practitioners. N Z Med J. 2000;113(1113):269-72.
37. Haynes R, Pearce J, Barnett R. Cancer survival in New Zealand: Ethnic, social and geographical inequalities. Social Science & Medicine. 2008;67(6):928-37.
38. Lewis S, Hales S, Slater T, Pearce N, Crane J, Beasley R. Geographical variation in the prevalence of asthma symptoms in New Zealand. N Z Med J. 1997;110(1049):286-9.
39. Goodyear-Smith F, Janes R. The New Zealand rural primary care workforce in 2005: more than just a doctor shortage. Aust J Rural Health. 2008;16(1):7.
40. Starfield B, Shi L, Macinko J. Contribution of primary care to health systems and health. Milbank Q. 2005;83(3):457-502.
41. Fisher ES, Wennberg DE, Stukel TA, Gottlieb DJ, Lucas FL, Pinder EL. The implications of regional variations in Medicare spending. Part 2: health outcomes and satisfaction with care. Annals of internal medicine. 2003;138(4):288-98.
42. Fisher ES, Wennberg DE, Stukel TA, Gottlieb DJ, Lucas FL, Pinder EL. The implications of regional variations in Medicare spending. Part 1: the content, quality, and accessibility of care. Annals of internal medicine. 2003;138(4):273-87.
43. Burton J. Rural Health Care in New Zealand. RNZCGP Occassional Paper Number 4. 1999.
44. Janes R. Benign neglect of rural health: is positive change on its way? New Zealand Family Physician. 1999;26(1):3.
45. Cameron J. Attracting young pharmacists to the regions, and keeping them there. . Pharmacy Today. 2017:2.
46. North N. Can New Zealand achieve self-sufficiency in its nursing workforce? J Clin Nurs. 2011;20:10.

47. Physiotherapy Board of New Zealand. Physiotherapy Board Workforce Demographics, Chapter 6. Physiotherapy Board of New Zealand Annual
Report 1 April 2015–31 March 2016.
48. Ministry of Health. A comparison of primary care provided by rural and non-rural general practices: the National Primary Care Survey (NatMedCa): 2001/02 Report 4. Wellington: Ministry of Health 2004
49. NOTE:Goodyear-Smith F, Janes R, New Zealand Institute of Rural Health. The 2005 Rural Health Workforce Survey. Wellington: Ministry of Health; 2006.
50. The Royal New Zealand College of General Practitioners. 2007 RNZCGP Membership Survey: General Practice in New Zealand Part III. Wellington: The RNZCGP; 2009.
51. The Royal New Zealand College of General Practitioners. 2008 RNZCGP Membership Survey. Wellington: The RNZCGP; 2009.
52. Wong DL, Nixon G. The rural medical generalist workforce: The Royal New Zealand College of General Practitioners' 2014 workforce survey results. J Prim Health Care. 2016;8(3):196-203.
53. Garces-Ozanne A, Yow A, Audas R. Rural practice and retention in New Zealand: an examination of New Zealand-trained and foreign-trained doctors. N Z Med J. 2011;124(1330):14-23.
54. Lawrenson R, Nixon G, Steed R. The Rural Hospital Doctors Workforce in New Zealand. Rural and Remote Health. 2011;11(1588).
55. Nixon G, Blattner K, Party NZRHDW. Rural hospital medicine in New Zealand: vocational registration and the recognition of a new scope of practice. N Z Med J. 2007;120(1259):U2654.
56. Nixon G, Blatter K. Recent Developments in Rural Medicine 1: Rural Hospital Medicine Special Scope. New Zealand Family Physician.35(6).
57. Dawson J, Nixon G. Recent Developments in Rural Hospital Medicine II: Experiential pathway to Fellowship of the Division of Rural Hospital Medicine. New Zealand Family Physician. 2008;35(6).
58. Blattner K, Nixon G, Gutenstein M, Davey E. A targeted rural postgraduate education programme - linking rural doctors across New Zealand and into the Pacific. Educ Prim Care. 2017;28(6):346-50.
59. Nixon G, Blattner K, Williamson M, McHugh P, Reid J. Training generalist doctors for rural practice in New Zealand. Rural Remote Health. 2017;17(1):4047.
60. International Statement for Rural Medical Generalism: Cairns Consensus. 2013 [Available from: https://www.acrrm.org.au/the-college-at-work/position-statements/policy/2015/06/10/international-statement-for-rural-medical-generalism-cairns-consensus.
61. Wootton J. President's message. Clinical courage. Can J Rural Med. 2011;16(2):45-6.
62. Poole P, Bagg W, O'Connor B, Dare A, McKimm J, Meredith K, et al. The Northland Regional-Rural program (Pukawakawa): broadening medical undergraduate learning in New Zealand. Rural Remote Health. 2010;10(1):1254.
63. Matthews C, Bagg W, Yielder J, Mogol V, P P. Does Pūkawakawa (the regional rural programme at the University of Auckland) influence workforce choice? N Z Med J. 2015;128:9.
64. Williamson M, Wilson R, McKechnie R, Ross J. Does the positive influence of an undergraduate rural placement persist into postgraduate years? Rural and Remote Health. 2011;12.
65. Poole P, Wilkinson TJ, Bagg W, Freegard J, Hyland F, Jo CE, et al. Developing New Zealand's medical workforce: realising the potential of longitudinal career tracking. N Z Med J. 2019;132(1495):65-73.
66. Willaimson M, Gormley A, Farry P. Otago Rural Hospitals Study: What do utilisation rates tell us about the performance of New Zealand rural hospitals? The New Zealand Medical Journal. 2006;119(1236):13.
67. Williamson M, Gormley A, Dovey S, Farry P. Rural hospitals in New Zealand: results from a survey. N Z Med J. 2010;123(1315):20-9.
68. Janes R. Rural hospitals in New Zealand. N Z Med J. 1999;112(1093):297-9.
69. Fearnley D, Mclean j, Wilkins G, Restieaux N, Nixon G. Audit of a collaborative care model suggests patients with acute myocardial infarction are not disadvantaged by treatment in a rural hospital. N Z Med J. 2002;115(1165):7.

70. Tang E, Wong C, Herbison P. Community hospital versus tertirary hospital comparison in the treatment and outcome of patients with acute coronary syndrome: A comparison New Zealand Experience. New Zealand Medical Journal. 2006;119(2078).
71. Reeve C, Humphreys J, Wakerman J. A comprehensive health service evaluation and monitoring framework. Eval Program Plann. 2015;53:91-8.
72. New Zealand Health Survey. Wellington, New Zealand: Ministry of Health; 2018 [Available from: https://www.health.govt.nz/nz-health-statistics/national-collections-and-surveys/surveys/new-zealand-health-survey.
73. ANZACS-QI Registry Auckland. New Zealand.: University of Auckland; [Available from: https://www.fmhs.auckland.ac.nz/en/soph/about/our-departments/epidemiology-and-biostatistics/research/view-study/research.html.
74. Fearnley D, Kerse N, Nixon G. The price of 'free'. Quantifying the costs incurred by rural residents attending publically funded outpatient clinics in rural and base hospitals. J Prim Health Care. 2016;8(3):204-9.
75. Rankin SL, Hughes-Anderson W, House AK, Heath DI, Aitken RJ, House J. Costs of accessing surgical specialists by rural and remote residents. ANZ J Surg. 2001;71(9):544-7.
76. 2016 Commonwealth Fund International health policy survey. New York: United States.: The Commonwealth Fund; 2018 [Available from: https://www.commonwealthfund.org/publications/journal-article/2016/nov/new-survey-11-countries-us-adults-still-struggle-access-and
77. Fraser J. Rural Health: A Literature Review for the National Health Committee. wwwrgpnorgnz/Network/media/documents//rural-health-literature-reviewpdf. 2006.
78. Kernick DP. Introduction to health economics for the medical practitioner. Postgrad Med J. 2003;79(929):147-50.
79. Goeree R, Vakaramoko D. Introduction to health economics and decision-making: Is economics relevant for the frontline clinician? Best Practice & Research Clinical Gastroenterology. 2013;27:813-44.
80. Blattner K, Nixon G, Dovey S, Jaye C, Wigglesworth J. Changes in clinical practice and patient disposition following the introduction of point-of-care testing in a rural hospital. Health Policy. 2010;96(1):7-12.
81. Koroheke-Rogers M, Blattner K. Kete pikau: A basket of knowledge - 'guidelines from back home'. Aust J Rural Health. 2018;26(5):350-2.
82. Nixon G, Blattner K, Dawson J, Dovey S, Black MA, Wilkins G, et al. Streptokinase antibodies in patients presenting with acute coronary syndrome in three rural New Zealand populations. J Clin Pathol. 2011;64(5):426-9.
83. Nixon G, Blattner K, Finnie W, Muirhead J, Rogers M, Lawrenson R, et al. The Scope of Point of Care Ultrasound in Rural New Zealand. Journal of Primary Health Care. 2018;10(3):224-36.
84. Donabedian A. The quality of care. How can it be assessed? JAMA. 1988;260(12):5.
85. Ministry of Health. Gap Analysis of Specialist Palliative Care in New Zealand: Providing a national overview of hospice and hospital-based services. 2009. Ministry of Health: Wellington
86. Ministry of Health, National Cardiac Surgery Update: and the formation of the New Zealand Cardiac Network. 2011. Ministry of Health: Wellington
87. Statistics New Zealand. Population - Census 2010. 2013. http://www.stats.govt.nz/browse_for_stats/population.aspx
88. Statistics New Zealand. Population - Census 2006. Accessed December 2013. http://www.stats.govt.nz/Census/2006CensusHomePage.aspx
89. Merkens BJ, Mowbray RD, Creeden L, Engels PT, Rothwell DM, Chan BT, et al. A rural CT scanner: evaluating the effect on local health care. Canadian Association of Radiologists Journal. 2006;57:224-31.
90. Lysdahl KB, Børretzen I. Geographical variation in radiological services: a nationwide survey. BMC Health Services Research. 2007;7(1):1-11.
91. Gorman, D. Promising future for general practice. New Zealand Doctor. 2010. Accessed December 2013. www.nzdoctor.co.nz/.../promising-future-for-general-practice.aspx
92. Schuur JD, Venkatesh AK. The growing role of emergency departments in hospital admissions. N Engl J Med. 2012;367(5):391-3.

93. Ajwani, S., T. Blakely, B. Robson, J. Atkinson and C. Kiro. Unlocking the numerator-denominator bias III: adjustment ratios by ethnicity for 1981–1999 mortality data. The New Zealand Census-Mortality Study. Journal of the New Zealand Medical Association. 116 (1175): p. 1-12. ISSN 1175 8716
94. Ministry of Health. Factors affecting Pacific peoples' health. 2011. Ministry of Health: Wellington. Accessed December 2013. http://www.health.govt.nz/our-work/populations/pacific-health/factors-affecting-pacificpeoples-health
95. Blakely T, M. Tobias, J. Atkinson et al. Tracking disparity: trends in ethnic and socioeconomic inequalities in mortality, 1981–2004. 2007. Ministry of Health: Wellington. Available from www.health.govt.nz
96. Ministry of Health. Ala Mo'ui: Pathways to Pacific Healthand Wellbeing 2010–2014. Wellington: Ministry of Health; 2010.http://www.health.govt.nz/publication/ala-moui-pathways-pacific-health-and-wellbeing-2010-2014 [accessed December 2013].
97. Ministry of Health. Whakata taka Tuarua Māori Health ActionPlan 2006–2011. Wellington: Ministry of Health; 2006.http://www.health.govt.nz/system/files/documents/publications/whakata taka-tuarua-action-plan.pdf [accessed December 2013].
98. Alter, D.A., et al. Geography and service supply do not explain socioeconomic gradients in angiography use after acute myocardial infarction. Canadian Medical Association Journal. 2003. 168(3): p. 261-264
99. Statistics New Zealand. 2013 Census population and dwelling tables – Queenstown-Lakes District. [cited 2016 December 23] Available from: www.stats.govt.nz/~/.../ Census/2013%20Census/data.../population.../queens- town-lakes.
100. Statistics New Zealand Commercial Accommodation Monitor. [cited 2016 April 20] Available from: http://www. queenstownnz.co.nz/Media/Statistics2_md/.
101. Accident Compensation Commission injury statistics tool. [cited 2016 March 14] Available from: http://www.acc.co.nz/about-acc/statistics/injury-statistics/index.htm#.
102. Stiell I, Well G, Vandemheen K. The Canadian CT Head rule for patients with minor head injury. Lancet. 2001;357(9266):1391-6.
103. Injury TB. Diagnosis, Acute Management and Rehabilitation. New Zealand Guidelines Group. July 2006. [cited 2016 February 12] Available from: www.acc.co.nz/PRD_ EXT_CSMP/groups/.../wim2_059414.pdf.
104. Kaji AH, Schriger D, Green S. Looking through the retrospectoscope: reducing bias in emergency medicine chart review studies. Ann Emerg Med. 2014;64(3):292-8.
105. Smits M, Dippel DW, de Haan GG, Dekker HM, Vos PE, Kool DR, et al. External validation of the Canadian CT Head Rule and the New Orleans Criteria for CT scanning in patients with minor head injury. JAMA. 2005;294(12):1519-25.
106. Injury TB. Diagnosis, Acute Management and Rehabilitation. New Zealand Guidelines Group. July 2006. [cited 2016 February 12] Available from: www.acc.co.nz/PRD_ EXT_CSMP/groups/.../wim2_059414.pdf.
107. Injury TB. Diagnosis, Acute Management and Rehabilitation. New Zealand Guidelines Group. July 2006. [cited 2016 February 12] Available from: www.acc.co.nz/PRD_ EXT_CSMP/groups/.../wim2_059414.pdf.
108. van der Naalt J, Hew JM, van Zomeren AH, Sluiter WJ, Minderhoud JM. Computed tomography and magnetic resonance imaging in mild to moderate head injury: early and late imaging related to outcome. Ann Neurol. 1999;46(1):70-8.
109. Muller K, Ingebrigtsen T, Wilsgaard T, Wikran G, Fagerheim T, Romner B, et al. Prediction of time trends in recovery of cognitive function after mild head injury. Neurosurgery. 2009;64(4):698-704; discussion
110. Yanagawa Y, Sakamoto T. Significance of minor traumatic lesions in focal head injuries. J Clin Neurosci. 2011;18(4):520-3.
111. Theadom A, Parmar P, Jones K, Barker-Collo S, Starkey NJ, McPherson KM, et al. Frequency and impact of recurrent traumatic brain injury in a population-based sample. J Neurotrauma. 2015;32(10):674-81.

112. Orlovska S, Pedersen MS, Benros ME, Mortensen PB, Agerbo E, Nordentoft M. Head injury as risk factor for psychiatric disorders: a nationwide register-based follow-up study of 113,906 persons with head injury. Am J Psychiatry. 2014;171(4):463-9.
113. Nixon G, Samaranayaka A, de Graaf B, McKechnie R, Rodwell P, Blattner K. The impact of a rural scanner in overcoming urban versus rural disparities in the utilisation of computed tomography. Aust J Rural Health. 2015;23(3):150-4.
114. Rural Expert Advisory Group to the Ministry of Health. Implementing the Primary Health Care Strategy in Rural New Zealand 2002. [cited 2016 Dec. 23] Available from: http://www.moh.govt.nz/notebook/nbbooks.nsf/0/5e56a47c1768d27ecc256c190076e807/$FILE/Rural Prima- ryHealthStrategyImplementation.pdf.
115. Australian Institute of Health and Welfare. Rural, regional and remote health: indicators of health status and determinants of health. 31 March 2008. [cited 2016 December 23] Available from: http://www.aihw.gov.au/publication-de tail/?id=64424680768libID=6442468074.
116. Pong RW, Desmeules M, Lagace C. Rural-urban disparities in health: how does Canada fare and how does Canada compare with Australia? Aust J Rural Health. 2009;17(1):58-64.
117. Anderson TJ, Saman DM, Lipsky MS, Lutfiyya MN. A cross-sectional study on health differences between rural and non-rural U.S. counties using the County Health Rankings. BMC Health Serv Res. 2015;15:441.
118. Singh R, Goebel LJ. Rural Disparities in Cancer Care: A Review of Its Implications and Possible Interventions. W V Med J. 2016;112(3):76-82.
119. Fleet R, Archambault P, Plant J, Poitras J. Access to emergency care in rural Canada: should we be concerned? CJEM 2013;15(4):191-3.
120. Injury TB. Diagnosis, Acute Management and Rehabilitation. New Zealand Guidelines Group. July 2006. [cited 2016 February 12] Available from: www.acc.co.nz/PRD_ EXT_CSMP/groups/.../wim2_059414.pdf.
121. Ginde A, Foianini A, Renner D, Valley M, Camargo C. Availability and quality of computed tomography and magnetic resonance imaging equipment in US emergency departments. Academic Emergency Medicine. 2008;15:780-3.
122. Joynt KE, Harris Y, Orav EJ, Jha AK. Quality of care and patient outcomes in critical access rural hospitals. JAMA. 2011;306(1):45-52.
123. Bishop CV, Drummond KJ. Rural neurotrauma in Australia: implications for surgical training. ANZ J Surg. 2006;76(1-2):53-9.
124. Hay K. Portable head computed tomography for rural centres. Can J Rural Med. 2010;15(3):125-6.
125. Todd AW, Anderson EM. CT scanning in stroke patients: meeting the challenge in the remote and rural district general hospital. Scott Med J. 2009;54(2):17-20.
126. Kelly JC, O'Callaghan A, Mc Mullin L, Clinton O, Binchy J. Management of traumatic head injuries in a rural Irish hospital: implications of the NICE guidelines. Ir J Med Sci. 2010;179(4):557-60.
127. Wiener RS, Schwartz LM, Woloshin S. Time trends in pulmonary embolism in the United States: evidence of overdiagnosis. Arch Intern Med. 2011;171(9):831-7.
128. Bourke L, Humphreys JS, Wakerman J, Taylor J. Understanding rural and remotehealth: Af ramework for analysis in Australia. Health & Place. 2012;18:7.
129. Huckle D. Point-of-care diagnostics: an advancing sector with nontechnical issues. Expert Rev Mol Diagn. 2008;8(6):679-88.
130. Nichols JH, Christenson RH, Clarke W, Gronowski A, Hammett-Stabler CA, Jacobs E, et al. Executive summary. The National Academy of Clinical Biochemistry Laboratory Medicine Practice Guideline: evidence-based practice for point-of-care testing. Clin Chim Acta. 2007;379(1-2):14-28; discussion 9-30.
131. (4) Guilbert R, Schnattner P, Sikaris K, Churilov L, et al. Review of the role and value of near patient testing in general practice. Report to the Pathology Section, Diagnostic and Technology Branch, Commonwealth Department of Health and Aged Care. 2001. http://www.health.gov.au.
132. Blatter K, Nixon G, Jaye C, Dovey S. Introducing point-of-care testing into a rural hospital setting: thematic analysis of interviews with providers. J Primary Health Care. 2010;2(1).

133. Salmond C, Crampton P, Sutton F. NZDep91: A New Zealand index of deprivation. Aust N Z J Public Health. 1998;22(7):835-7.
134. Jaine R, Baker M, Venugopal K. Epidemiology of acute rheumatic fever in New Zealand 1996-2005. J Paediatr Child Health. 2008;44(10):564-71.
135. Reducing inequalities in health. Wellington: Ministry of Health; 2002.
136. Lyon M, Blaivas M, Brannam L. Use of emergency ultrasound in a rural ED with limited radiology services. The American Journal of Emergency Medicine. 2005;23(2):212-4.
137. McLean R, Malek S, Corish J, Sienkiewicz G. Utilisation and clinical efficacy of echocardiography in a regional hospital. Aust J Rural Health. 2006;14(2).
138. Tukuitonga C, Bindman A. Ethnic and gender differences in the use of coronary artery revascularisation procedures in New Zealand. N Z Med J. 2002;115(1152):179-82.
139. Aroney C, Aylward P, Kelly A, Chew D. Guidelines for the management of acute coronary syndromes 2006. Medical Journal of Australia. 2006;184(S8).
140. Montalvo V. GPEP1 audit: rural hospital transfers. New Zealand Family Physician. 2008;35(5):328–9.
141. Blatter K, Beazley C, Nixon G, Herd G, Wigglesworth J, Rogers-Koroheke M. The impact of the introduction of a point-of-care haematology analyser in a New Zealand rural hospital with no onsite laboratory. Rural and Remote Health. 2019;19(2).
142. Miller R, Stokes T, Nixon G. Point-of-care troponin use in New Zealand rural hospitals: a national survey New Zealand Medical Journal. 2019;132(1493).
143. Miller R, Nixon G. The assessment of acute chest pain in New Zealand rural hospitals utilising point-of-care troponin. Journal of Primary Health Care. 2018;10(1).
144. Declaration of Alma-Ata. in international Conference on Primary Health Care. 1978. Alma-Ata, USSR: World Health Organization.
145. Starfield B. Primary care: Balancing health needs, services and technology.: Oxfor University Press; 1998.
146. Humphreys JS, Jones JA, Jones MP, Mildenhall D, Mara PR, Chater B, et al. The influence of geographical location on the complexity of rural general practice activities. Med J Aust. 2003;179:416-20.
147. Salmond C, Crampton P, King P, Waldegrave C. NZiDep: a New Zealand index of socioeconomic deprivation for individuals. Soc Sci Med. 2006;62(6):1474-85.
148. Hokianga Health Enterprises Trust, Annual Report. 2008.
149. St-Louis P. Status of point-of-care testing: promise, realities, and possibilities. Clin Biochem. 2000;33(6):427-40.
150. Thomas D. A general inductive approach for analysing qualitative data. Am J Eval. 2006;27.
151. Humphreys JS, Wakerman J, Wells R, Kuipers P, Jones J, Entwiste P. Beyond workforce: a systematic solution for health service provision in small rural remote communities. Medical Journal of Australia. 2008;188(8):S77-80.
152. King A. The Primary Health Care strategy. Wellington: Ministry of Health; 2001.
153. Reducing inequalities in health. Wellington: Ministry of Health; 2002.
154. Conaglen P, Sebastian C, Jayaraman C, Abraham A, Makkada V, Devlin G. Management of unstable angina and non-ST-elevation myocardial infarction: do cardiologists do it better? A comparison of secondary and tertiary centre management in New Zealand. NZ Med J. 2004;117(1194).
155. Ellis C, Devlin G, P. M, Elliott J, Williams M, Gamble G, et al. Acute Coronary Syndrome patients in New Zealand receive less invasive management when admitted to hospitals without invasive facilities. NZ Med J. 2004;117(1197).
156. Domes T, Szafran O, Bilous C, Olson O, Spooner GR. Acute myocardial infarction: quality of care in rural Alberta. Can Fam Physician. 2006;52:68-9.
157. Heller R, O'Connell R, D'Este C, Lim L, Fletcher P. Differences in cardiac procedures among patients in metropolitan and non-metropolitan hospitals in New South Wales after acute myocardial infarction and angina. Aust J Rural Health. 2000;8(6):310-7.
158. Sanborn MD, Manuel DG, Ciechanska E, Lee DS. Potential gaps in congestive heart failure management in a rural hospital. Can J Rural Med. 2005;10(3):155-61.

159. Birkhead JS, Weston C, Lowe D. Impact of specialty of admitting physician and type of hospital on care and outcome for myocardial infarction in England and Wales during 2004-5: observational study. BMJ. 2006;332(7553):1306-11.
160. Clark RA, Coffee N, Turner D, Eckert KA, van Gaans D, Wilkinson D, et al. Application of geographic modeling techniques to quantify spatial access to health services before and after an acute cardiac event: the Cardiac Accessibility and Remoteness Index for Australia (ARIA) project. Circulation. 2012;125(16):2006-14.
161. Westbrooke I, Baxter J, Hogan J. Are Māori under-served for cardiac interventions? N Z Med J. 2001;114(1143):484-7.
162. Brabyn L, Barnett R. Population need and geographical access to general practitioners in rural New Zealand. N Z Med J. 2004;117(1199):U996.
163. Panelli R, Gallagher L, Kearns R. Access to rural health services: research as community action and policy critique. Soc Sci Med. 2006;62(5):1103-14.
164. Alter D, Naylor C, Austin P, Chan BT, Tu J. Geography and service supply do not explain socioeconomic gradients in angiography use after acute myocardial infarction. Canadian Medical Association Journal. 2003;168:261-4.
165. Ministry of Health, Māori Health Statistics. 2006.
166. Hurune PN, O'Shea JM, Maguire GP, Hewagama SS. Utility of exercise electrocardiography testing for the diagnosis of coronary artery disease in a remote Australian setting. Med J Aust. 2013;199(3):201-4.
167. Gibbons RJ, Balady GJ, Timothy Bricker J, Chaitman BR, Fletcher GF, Froelicher VF, et al. ACC/AHA 2002 guideline update for exercise testing: summary article. Journal of the American College of Cardiology. 2002;40(8):1531-40.
168. Christman MP, Bittencourt MS, Hulten E, Saksena E, Hainer J, Skali H, et al. Yield of downstream tests after exercise treadmill testing: a prospective cohort study. J Am Coll Cardiol. 2014;63(13):1264-74.
169. Evans CH, Karunaratne HB. Interpretation of the results. (Exercise Stress Testing for the Family Physician, part 2). American Family Physician. 1992;45:679-89.
170. Cubo-Romano P, Torres-Macho J, Soni NJ, Reyes LF, Rodriguez-Almodovar A, Fernandez-Alonso JM, et al. Admission inferior vena cava measurements are associated with mortality after hospitalization for acute decompensated heart failure. Journal of Hospital Medicine (Online). 2016;11(11):778-84.
171. Gauld R. Questions about New Zealand’s health system in 2013, its 75th anniversary year. N Z Med J. 2013;126:68-74.
172. Moore CL, Copel JA. Point-of-care ultrasonography. N Engl J Med. 2011;364(8):749-57.
173. Minardi J, Davidov D, Denne N, Haggerty T, Kiefer C, Tillotson R, et al. Bedside ultrasound: advanced technology to improve rural healthcare. West Virginia Medical Journal.109(4):28-33.
174. Soni NJ, Lucas BP. Diagnostic point-of-care ultrasound for hospitalists. Journal of Hospital Medicine. 2015;10(2):120-4.
175. Flynn CJ, Weppler A, Theodoro D, Haney E, Milne WK. Emergency medicine ultrasonography in rural communities. Can J Rural Med. 2012;17(3):99-104.
176. Leger P, Fleet R, Maltais-Giguere J, Plant J, Piette E, Legare F, et al. A majority of rural emergency departments in the province of Quebec use point-of-care ultrasound: a cross-sectional survey. BMC Emerg Med. 2015;15:36.
177. Nelson BP, Melnick ER, Li J. Portable ultrasound for remote environments, part II: current indications. J Emerg Med. 2011;40(3):313-21.
178. Blaivas M, Kuhn W, Reynolds B, Brannam L. Change in Differential Diagnossi and Patient Management With the Use of Portable Ultrasoudn in a Remote Setting. Wilderness and Environmental Medicine. 2005;16.
179. Postgraduate Certificate in Clinician Performed Ultrasound. University of Otago. https://www.otago.ac.nz/courses/qualifications/pgcertcpu.html Accessed Nov. 2019
180. Glazebrook R, Manahan D, Chater AB. Evaluation of an ultrasound program (intermediate obstetric and emergency medicine) for Australian rural and remote doctors. Australian Journal of Rural Health. 2005;13(5):295-9.

181. Policy on credentialing for emergency medicine ultrasonography: Trauma Examination and suspected AAA. Australasian College of Emergency Medicine. Docuement P22. Feb-16
182. Zhang W, Creswell J. The Use of "Mixing" Procedure of Mixed Methods in Health Services Research. Medical Care. 2013;51(8).
183. Agresti A. Categorical Data Analysis, 3rd Edition, New York:Wiley. 2013.
184. Bates D, Maechler M, Bolker B, Walker S. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software. 2015;67(1).
185. Nagaraj G, Chu M, Dinh M. Emergency clinician performed ultrasound: availability, uses and credentialing in Australian emergency departments. Emergency Medicine Australasia. 2010;22(4):296-300.
186. Craig S, Egerton-Warburton D, Mellett T. Ultrasound use in Australasian emergency departments: A survey of Australasian College for Emergency Medicine Fellows and Trainees. Emergency Medicine Australasia. 2014;26(3):268-73.
187. Jaye C, Mason Z, Miller D. "Tossing out the baby with the bath water": New Zealand general practitioners on maternity care. Medical Anthropology. 2013;32(5):448-66.
188. Glazebrook R, Manahan D, Chater B, Barker P, Row D, Steele B, et al. Educational Needs of Rural and Remote Australian Non-Specialist Medical Practitioners For Obstetric Ultrasound. Australian Journal of Rural Health. 2004;12(2):73-80.
189. Lightfoot N, Strasser R, Maar M, Jacklin K. Challenges and rewards of health research in northern, rural, and remote communities. Ann Epidemiol. 2008;18(6):507-14.
190. Postgraduate Certificate in Clinician Performed Ultrasound. University of Otago. https://www.otago.ac.nz/courses/qualifications/pgcertcpu.html Accessed Nov. 2019
191. Farmer J, Munoz S-A, Daly C. Being rural in rural health research. Health & Place. 2012;18(5):3.
192. Health Research Council of New Zealand. Guidelines for Researchers on Health Research Involving Māori Health Research Council of New Zealand, 2010.
193. Postgraduate Certificate in Clinician Performed Ultrasound. University of Otago. https://www.otago.ac.nz/courses/qualifications/pgcertcpu.html Accessed Nov. 2019
194. Ultrasound Guidelines: Emergency, Point-of-Care and Clinical Ultrasound Guidelines in Medicine. Annals of Emergency Medicine. 2017;69(5):e27-e54.
195. Bentz S, Jones J. Towards evidence-based emergency medicine: best BETs from the Manchester Royal Infirmary. Accuracy of emergency department ultrasound scanning in detecting abdominal aortic aneurysm. Emerg Med J. 2006;23(10):803-4.
196. Arntfield RT, Millington SJ. Point of care cardiac ultrasound applications in the emergency department and intensive care unit--a review. Curr Cardiol Rev. 2012;8(2):98-108.
197. Herzog R, Elgort DR, Flanders AE, Moley PJ. Variability in diagnostic error rates of 10 MRI centers performing lumbar spine MRI examinations on the same patient within a 3-week period. Spine J. 2017;17(4):554-61.
198. Moncada DC, Rueda ZV, Macías A, Suárez T, Ortega H, Vélez LA. Reading and interpretation of chest X-ray in adults with community-acquired pneumonia. The Brazilian Journal of Infectious Diseases. 2011;15(6):540-6.
199. Kendall JL, Hoffenberg SR, Smith RS. History of emergency and critical care ultrasound: the evolution of a new imaging paradigm. Crit Care Med. 2007;35(5 Suppl):S126-30.
200. Cipollini F, Cipollini M. A critical evaluaiton in the delivery of the ultrasound practice: the point of view of the Internal Medicin hospitalist. Italian Journal of Medicine. 2015;9:1-4.
201. Nixon G, Blattner K, Lawrenson R, Kerse N. The Scope of Point of Care Ultrasound Practice in Rural New Zealand. J Prim Health Care - Submitted 2018
202. Dalziel PJ, Noble VE. Bedside ultrasound and the assessment of renal colic: a review. Emerg Med J. 2013;30(1):3-8.
203. Davis C, Chrisman J, Walden P. To scan or not to scan? Detecting urinary retention. Nursing Made Incredibly Easy! 2012;10(4):53-4.
204. Policy on the focused use of focused ultrasound in emergency medicine. Australasian College of Emergency Medicine. 2016.

205. American College of Emergency Physicians. Ultrasound guidelines. https://www.acep.org/Clinical---Practice-Management/Ultrasound/#sm.0000da11goxv2crrv5z21kcm7kzxv
206. Nixon G, Blatter K, Koroheke-Rogers M, Muirhead L, Finnie W, Kerse N. Point of Care Ultrasound in Rural New Zealand: Safety, Quality and Impact on Patient Mangement. Aust J Rural Health. Submitted 2018
207. https://www.medcalc.org/calc/diagnostic_test.php
208. Weatherall M, Harwood M. The accuracy of clinical assessment of bladder volume. Arch Phys Med Rehabil. 2002;83(9):1300-2.
209. Hvarness H, Skjoldbye B, Jakobsen H. Urinary bladder volume measurements: comparison of three ultrasound calculation methods. Scand J Urol Nephrol. 2002;36(3):177-81.
210. Davison R, Cannon R. Estimation of central venous pressure by examination of jugular veins. American Heart Journal. 1974;87(3):279-82.
211. Rizkallah J, Jack M, Saeed M, Shafer LA, Vo M, Tam J. Non-invasive bedside assessment of central venous pressure: scanning into the future. PLoS ONE [Electronic Resource]. 2014;9(10):e109215.
212. Cook DJ, Simel DL. Does this patient have abnormal central venous pressure? JAMA. 1996;275(8):630-4.
213. Lipton B. Estimation of central venous pressure by ultrasound of the internal jugular vein. Am J Emerg Med. 2000;18(4):432-4.
214. Mantuani D, Frazee BW, Fahimi J, Nagdev A. Point-of-Care Multi-Organ Ultrasound Improves Diagnostic Accuracy in Adults Presenting to the Emergency Department with Acute Dyspnea. The Western Journal of Emergency Medicine. 2016;17(1):46-53.
215. Ciozda W, Kedan I, Kehl DW, Zimmer R, Khandwalla R, Kimchi A. The efficacy of sonographic measurement of inferior vena cava diameter as an estimate of central venous pressure. Cardiovascular Ultrasound. 2016;14:33.
216. Long E, Oakley E, Duke T, Babl FE. Does Respiratory Variation in Inferior Vena Cava Diameter Predict Fluid Responsiveness: A Systematic Review and Meta-Analysis. Shock. 2017;47(5):550-9.
217. Saha NM, Barbat JJ, Fedson S, Anderson A, Rich JD, Spencer KT. Outpatient Use of Focused Cardiac Ultrasound to Assess the Inferior Vena Cava in Patients With Heart Failure. American Journal of Cardiology. 2015;116(8):1224-8.
218. Schmidt GA, Koenig S, Mayo PH. Shock: ultrasound to guide diagnosis and therapy. Chest. 2012;142(4):1042-8.
219. Lee CW, Kory PD, Arntfield RT. Development of a fluid resuscitation protocol using inferior vena cava and lung ultrasound. Journal of Critical Care. 2016;31(1):96-100.
220. Pellicori P, Carubelli V, Zhang J, Castiello T, Sherwi N, Clark A, et al. IVC Diameter in Heart Failure. Relationships and Prognostic Significance. JACC: Cardiovascular Imaging. 2013;6(1).
221. Nixon G, Blattner K, Koroheke-Rogers M, Muirhead J, Finnie WL, Lawrenson R, et al. Point-of-care ultrasound in rural New Zealand: Safety, quality and impact on patient management. Aust J Rural Health. 2018;26(5):342-9.
222. Uthoff H, Siegemund M, Aschwanden M, Hunziker L, Fabbro T, Baumann U, et al. Prospective comparison of noninvasive, bedside ultrasound methods for assessing central venous pressure. Ultraschall in der Medizin. 2012;33(7):E256-62.
223. Socransky S, Lang E, Bryce R, Betz M. Point-of-Care Ultrasound for Jugular Venous Pressure Assessment: Live and Online Learning Compared. Cureus. 2017;9(6):e1324.
224. ED Ultrasound Committee. Policy on credentialing for emergency medicine ultrasonography: Trauma Examination and suspected AAA. Australasian College of Emergency Medicine. Feb-2016.
225. Nair N, Shaw C, Sarfati D, Stanley J. Abdominal aortic aneurysm disease in New Zealand: epidemiology and burden between 2002 and 2006. New Zealand Medical Journal. 2012;125(1350).
226. Marston WA, Ahlquist R, Johnson Jr G, Meyer AA. Misdiagnosis of ruptured abdominal aortic aneurysms. Journal of Vascular Surgery. 1992;16(1):17-22.
227. Borrero E, Queral LA. Symptomatic Abdominal Aortic Aneurysm Misdiagnosed as Nephroureterolithiasis. Annals of Vascular Surgery. 1988;2(2):145-9.
228. https://www.medcalc.org/calc/diagnostic_test.php Accessed 25 July 2018

229. Rubano E, Mehta N, Caputo W, Paladino L, Sinert R. Systematic review: emergency department bedside ultrasonography for diagnosing suspected abdominal aortic aneurysm. Academic Emergency Medicine. 2013;20(2):128-38.
230. Nural MS, Yardan T, Guven H, Baydin A, Bayrak IK, Kati C. Diagnostic value of ultrasonography in the evaluation of blunt abdominal trauma. Diagn Interv Radiol. 2005;11(1):41-4.
231. Smith J. Focused assessment with sonography in trauma (FAST): should its role be reconsidered? Postgraduate Medical Journal. 2010;86(1015):285-91.
232. Implementing Research. A guideline for health researchers. Health Research Council of NZ. Wellington NZ. Accessed Sept. 2019. http://www.hrc.govt.nz/sites/default/files/Implementing%20Research%20-%20A%20guideline%20for%20health%20researchers.pdf
233. National Rural Health Alliance. Australia's health system needs re-balancing: a report on the shortage of primary care services in rural and remote areas. Canberra, Australia.; 2011.
234. Weinhold I, Gurtner S. Understanding shortages of sufficient health care in rural areas. Health Policy. 2014;118(2):201-14.
235. Stensland J, Akamigbo A, Glass D, Zabinski D. Rural and urban Medicare beneficiaries use remarkably similar amounts of health care services. Health Aff (Millwood). 2013;32(11):2040-6.
236. National Rural Health Alliance. Australia's health system needs re-balancing: a report on the shortage of primary care services in rural and remote areas
. Canberra, Australia.; 2011.
237. Sibley LM, Weiner JP. An evaluation of access to health care services along the rural-urban continuum in Canada. BMC Health Services Research. 2011;11(1):20.
238. Chan L, Hart LG, Goodman DC. Geographic access to health care for rural Medicare beneficiaries. J Rural Health. 2006;22(2):140-6.
239. Swan GM, Selvaraj S, Godden DJ. Clinical peripherality: development of a peripherality index for rural health services. BMC Health Serv Res. 2008;8(23):23.
240. Pong RW, Pitblado JR. Geographpic Distribution of Physicians in Canada: Beyond How Many and Where. Ottawa, Canada.: Canadian Institute for Health Information; 2005.
241. Australia's Health 2018. Canberra, Australia.: Australian Institute of Health and Welfare.
242. Goodman DC, Fisher ES, Stukel TA, Chang C. The distance to community medical care and the likelihood of hospitalization: is closer always better? . Am J Public Health. 1997;87:1144-50.
243. Lysdahl KB, Ingelin B. Geographical variation in radiological services: a nationwide survey. BMC Health Services Research. 2007;7:21.
244. Nixon G. Coronary artery surgery and the Māori. N Z Med J. 1986;99(800):290.
245. Curtis E, Harwood M, Riddell T, Robson B, Harris R, Mills C, et al. Access and society as determinants of ischaemic heart disease in indigenous populations. Heart Lung Circ. 2010;19(5-6):316-24.
246. Cormack DM, Harris RB, Stanley J. Investigating the relationship between socially-assigned ethnicity, racial discrimination and health advantage in New Zealand. PLoS One. 2013;8(12):e84039.
247. Harris R, Robson B, Curtis E, Purdie G, Cormack D, Reid P. Māori and non-Māori differences in caesarean section rates: a national review. N Z Med J. 2007;120(1250):U2444.
248. Aghajafari F, Tapley A, Sylvester S. Procedural skills of Australian general practice registrars: A cross-sectional analysis. . Australian family physician 2017;46(6):429.
249. Eley DS, Leung JK, Campbell N, Cloninger CR. Tolerance of ambiguity, perfectionism and resilience are associated with personality profiles of medical students oriented to rural practice. Medical Teacher. 2017;39(5):512-9.
250. Blatter K, Ward C. Point of care testing in Hokianga Hospital or 'How to get a good night's sleep in a lab-free zone.'. NZ J Med Lab Sci. 2011;65:3.
251. Rominger AH, Gomez GAA, Elliott P. The implementation of a longitudinal POCUS curriculum for physicians working at rural outpatient clinics in Chiapas, Mexico. Crit Ultrasound J. 2018;10(1):19.
252. Krasnik A. The concept of equity in health services research. Scand J Soc Med. 1996;24(1):2-7.