Construction and use of mapping techniques to describe the geographical distribution of medication dispensing for the secondary prevention of atherosclerotic CVD in New Zealand: VIEW-2

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Abstract

Background The Health Quality & Safety Commission (HQSC) is developing Atlases of Healthcare Variation in New Zealand. We were invited to create and map the sociogeographic distribution of medication dispensing patterns among people with atherosclerotic cardiovascular disease (CVD).

Methods We developed two interactive online atlas ‘templates’ demonstrating geographical variations in CVD medication dispensing using InstantAtlas. Each template provides stratified results in tabular, graphical and map format. In the ‘Standard’ template proportions were mapped according to standard deviations from the mean, while the ‘Advanced’ template used a ‘heat-map’ classification to show DHB-level variations. Furthermore, we added commentaries describing the variations present and provided questions of potential interest for users.

Results The Standard template was best suited for DHB-level variations relative to a specific age, gender, or ethnic group but less effective for showing comparisons between two groups (e.g. Māori and Pacific).

By contrast, the fixed legend and ‘radar plot’ in the Advanced template highlighted variations in medication dispensing rates geographically and sociodemographically more effectively.

Conclusions Geographical mapping of unwarranted variations in effective care requires careful consideration. Our experience from developing this CVD atlas is documented here for developers of other components of the Atlas of Healthcare Variation in New Zealand.

Unwarranted variation in healthcare, defined as delivery of care that is not consistent with a patient’s preference or related to a patient’s underlying illness, can differ dramatically between clinicians, health care organizations, regions and countries. This variation can be described through pictorially mapping geographical differences in health care as pioneered by the influential Dartmouth Atlas of Healthcare project (www.dartmouthatlas.org).

The Dartmouth group produced online atlases investigating variations in American health and healthcare using a statistically robust approach that is accessible to clinicians, researchers and the general public. Due to the increased availability and quality of electronic health records supporting the development of cohorts from routine health databases in recent years, countries such as Italy, Germany, England,
Australia and New Zealand, have been able to follow suit and investigate their own national geographical differences in health care.

Categorisation of unwarranted variation can be carried out according to variation in preference-sensitive care, supply-sensitive care, and effective care. Preference-sensitive care involves trade-offs where there are (at least) two valid alternative treatments available (e.g. back surgery or conservative therapy for a herniated disc). Supply-sensitive care relates to the availability of hospitals and specialist care; the more health services allocated per capita to a given population, the greater the frequency of use.

Lastly, effective care relates to a therapy or intervention that has proven effectiveness for health outcomes and where there are no significant trade-offs. One example of effective care is the use of statins, anticoagulant/antiplatelet, and blood pressure-lowering medications (also known as triple therapy) for patients who have sustained a heart attack, stroke, or other atherosclerotic cardiovascular (CVD) events.

In 2011 we were asked by the Health & Quality Safety Commission (HQSC) to construct an Atlas depicting the extent of social and geographical variation in the dispensing of the triple therapy medications among the New Zealand resident population aged 30–79 years with existing CVD. This would form a part of the newly developed New Zealand Atlas of Health Care Variation. The purpose of this Atlas was to stimulate questions, and in a shared community domain, debate why the depicted variations exist.

In this paper we briefly describe the construction of the CVD cohort from routine national health databases and then the use of mapping techniques and software functionalities to develop the online CVD atlas for the dispensing of evidence-based triple therapy. Furthermore, in this paper, we document our experience from developing this CVD atlas to guide others in their development of subsequent Atlases of Healthcare Variation in New Zealand.

**Methods**

The New Zealand Atlas of Healthcare Variation: atherosclerotic CVD Management – cohort definition. Anonymised data from national hospitalisation, primary health organisation (PHO) enrolment, mortality and pharmaceutical dispensing datasets were used to identify all New Zealand residents aged 30–79 years, still alive in the year 2011 and in contact with the health system between 2009 and 2011, who had been discharged from hospital between 01/01/2001 and 31/12/2010 with atherosclerotic CVD. Stratifying covariates were age, gender, ethnic group (Māori, Pacific, Indian, Other) and NZ deprivation index categorised into quintiles of deprivation. The data linkage processes, definitions of ischaemic CVD, ICD codes and covariates are described in detail in the accompanying paper by Kerr et al. and in summary at [http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/projects/atlas-of-healthcare-variation/atherosclerotic-disease/](http://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/projects/atlas-of-healthcare-variation/atherosclerotic-disease/).

We used each patient’s most recent interaction with the publicly-funded health system (i.e. GP visit, pharmaceutical dispensing, laboratory testing, in-patient and out-patient service) between 1 January 2009 and 31 December 2010 to identify the Census Area Unit representing their residential address. In addition, the CAU was used to identify the District Health Board (DHB) and National Cardiac Network Region the patient lived in. While analyses by area-level deprivation (e.g. NZDep2006) are possible (and presented in the accompanying paper by Kerr et al.), presenting deprivation results at the DHB level is not appropriate. Deprivation indices are typically designed for small geographic areas (e.g. neighbourhoods) and the larger administrative areas such as DHBs likely mask pockets of neighbourhoods whose deprivation circumstances are significantly better or worse than the average for a given DHB.
Measuring medication dispensing proportions—A person was considered to be adequately maintained on atherosclerotic CVD preventive medications (antiplatelet/anticoagulant, blood pressure lowering drug, statin or all three medications [triple therapy]) regularly if they had been dispensed these in at least three out of the four quarters of 2011. We calculated the proportion of the population in each DHB consistently dispensed these medications and the corresponding 95% Confidence Intervals (95% CIs), by age group, gender and ethnicity using Stata version 12. In some DHBs where the denominator for particular strata were small (e.g. the Pacific population in the West Coast), extreme values such as 0% or 100% were possible, for which CIs could not be calculated. Therefore, in all of our analyses, the denominator population was defined as the population+1, which enabled the calculation of 95% CIs for all data combinations.

In this study, the 95% Confidence Intervals were used to determine whether the proportion of medication dispensing in a given DHB was significantly different to the national average. The inclusion of confidence intervals in this study also acknowledges that we excluded the small proportion of patients that were admitted to a private hospital for an ischaemic event.

Geographical scale—Since 2000, there have been 21 DHBs responsible for the health of their local populations. In May 2010, the Southland and Otago DHBs amalgamated to form the new Southern DHB, reducing the number of DHBs across the country to 20. In this study, however, we kept the Otago and Southland DHBs separate because the two regions have quite different socio-demographic structures.

In 2009 the National Clinical Cardiac Network of New Zealand was formed. This Network groups adjacent DHBs into four service regions: Northern (Northland, Waitemata, Auckland, Counties Manukau); Midland (Waikato, Lakes, Bay of Plenty, Tairawhiti, Taranaki); Central (Hawke's Bay, MidCentral, Whanganui, Capital and Coast, Hutt Valley, Wairarapa, Nelson Marlborough); and Southern (West Coast, Canterbury, South Canterbury, Otago, Southland).

Instant Atlas software—Consistent with existing Atlases of Healthcare Variation published in New Zealand we used InstantAtlas™ software. This software integrates data from GIS and Excel to produce an interactive atlas in either HTML or Adobe Flash format, according to a pre-defined map template. For example, the Single Map Template allows users to present their data as a single map in conjunction with a table and one or more graphs (e.g. bar graph, pie chart, time series plot, box-and-whisker plot).

The Area Profile template also combines a single map and table but users can choose between vertical or horizontal bar charts or radar plots. A horizontal bar chart can demonstrate medication dispensing for different subpopulations, for example by ethnicity, and indicate how a particular DHB is performing relative to the cardiac network region’s average. By contrast, the concentric circles underpinning the Radar plot can be used to show medication dispensing proportions for every age, gender and ethnic group.

Users can modify the design and configuration of their InstantAtlas projects, but it is not possible to amalgamate functions in the Area Profile template such as a radar plot with the Single Map template. All of the elements in an InstantAtlas project are linked, so when a user selects data from the map, corresponding information in the table and graphs are also selected.

The numerators (number of people consistently dispensed medications), denominators (total number of people with atherosclerotic CVD), proportions and CIs calculated in Stata for each age band, gender and ethnicity were imported into InstantAtlas for online mapping. Our standard template comprised a Single Map template, integrating a single DHB-level map, table, bar chart of medication dispensing proportions by gender, age-group and ethnicity.

We used the HQSC’s style guide for the standard template, which presents data for a particular gender, ethnicity or age group as the standard deviation (SD) from the mean. The Standard Deviation legend in InstantAtlas classifies DHBs according to the number of SDs the medication dispensing proportion lies above or below the national mean, for the medication and population sub-group currently being displayed. The calculation of the SDs for display purposes is based purely on the distribution of the medication dispensing proportions, not the raw numerator and denominator values.

The Standard Deviation legend is calculated separately for each population group (e.g. Māori, Pacific), which ensures that ‘outliers’ will be seen for each map according to the light-grey to dark-blue colour ramp. Following the HQSC’s style guide, those DHBs shaded light-grey (i.e. ≥1 SD below the mean) are defined as ‘lowest’ in the legend, while those DHBs with medication dispensing proportions ≥1 SD
above the mean are defined as ‘highest’. However, caution is required when interpreting variations in levels of medication dispensing between population groups.

We recommend referring to the bar charts and the graphical depiction of confidence intervals above each bar to determine whether the regional variation seen on the map is likely to be statistically significant.

The Advanced template developed for this study was derived from the Area-Profile template and combines the single DHB-level map with a table, bar chart, commentary and a radar plot. We also included additional design features such as a button to switch the display between the radar plot and the tabular data, or the inclusion of comparison areas in which users can compare variations in the proportion of people taking different medications in their DHB with the national or cardiac network regional patterns.

Whereas the legend (proportion dispensed and standard deviation) of the standard template changes every time a user chooses another variable of interest, the Advanced template uses a fixed ‘heat-map’ legend comprising four classes (≤55%, 56-65%, 66-75% and >75%) to indicate medication dispensing proportions. The salmon-to-blue colour scheme (lowest category to highest category) used for the heat maps enables users to compare rates between age or ethnic groups in their DHB in relation to clinical best practice.

**Results**

**Population distribution**—The epidemiology of CVD medication dispensing patterns is described in the accompanying paper by Kerr et al in this issue of the *NZMJ*.

In brief, we identified 86,256 patients aged 30-79 years who were survivors of an atherosclerotic CVD event in 2000-2010, of whom 57,908 (67%) were male, 29,138 (34%), 17,702 (21%), 20,317 (24%) and 19,099 (22%) lived in the Northern, Midlands, Central and Southern Cardiac Regions.

Patients of “Other” ethnicities accounted for 79% of the participants (most of whom were New Zealand European). Māori comprised the second-largest group (10,958 patients, 13% of cohort), followed by Pacific peoples (4,845 patients, 6% of cohort) and Indians (1,993 patients, 2% of cohort).

**Standard template format maps**—Figure 1 outlines the layout of the standard template and maps the geographical distribution of using triple therapy dispensing by DHB as an example. The Data Explorer (Figure 1a) allows the user to display the proportions of people dispensed the therapy of interest (triple therapy, statins, BPL, anti-coagulant/antiplatelets, or on both statins and BPL), by gender, age group (30-39, 40-49, 50-59, 60-69 and 70-79 years) or ethnicity (Māori, Pacific, Indian, Other Asian, or European and Others [NZEO]). This interactive standard template is published as part of the HQSC’s *New Zealand Atlas of Healthcare Variation* (http://www.hqsc.govt.nz/assets/Health-Quality-Evaluation/CVD_standard/atlas.html).

The map (Figure 1b) shows the variation in triple therapy medication dispensing using the standard deviation classification technique. The HQSC style displays DHBs using a light grey-dark blue colour ramp, with lighter shades depicting areas with lower levels of medication dispensing (Figure 1c).

The elements of the atlas are all linked, so that when a user hovers their mouse over a DHB on the map, that DHB is simultaneously highlighted in green on the map, bar chart (Figure 1d), and the table (Figure 1e). Similarly, clicking a particular bar on the graph or DHB on the map selects the data and is displayed in purple.
Given the relatively low populations of Pacific and South Asian patients in our cohort, some cells in the data tables have very few patients. Therefore, we suppress medication adherence results for DHBs where there are fewer than 10 residents. In these situations, we assign a distinct colour to the affected DHBs and remove the data from the bar graphs. The corresponding table reports the population as <10 and the prevalence is not published.

The legend (Figure 1c) is also interactive, so clicking on the darkest shade of blue (i.e. ≥1SD from the mean) selects the corresponding DHBs on the map, and the corresponding bars on the extreme right hand side of the bar graph. Note that the legend (Figure 1c) only provides labels for the ≥1SD below the mean (“lowest”) and ≥1SD above the mean (“highest”) and is consistent for all therapy/demography combinations. The mean is calculated for the current display (i.e. triple therapy for all persons) and apportions the data range (54.1% to 65.6%) into 6 groups with a bandwidth of 0.5 SD from the mean.

The advantage of the bar graph (Figure 1d) in the standard template is its ability to show the proportions of medications dispensed and the corresponding 95% confidence intervals by DHB and in relation to the national average for the therapy/strata of interest. Similarly, the standard template includes the DHB-level results as a table (Figure 1e) to report the proportions but also to provide the CVD patient population in each DHB for the map of interest.

In Figure 1, the West Coast DHB is shaded purple on the map and bar graph highlighting the highest proportion of the population consistently dispensed triple therapy (65.6%). Figure 1e informs the user that there were only 719 CVD patients aged 30-79 living in the West Coast DHB in 2011.

To further add context to the CVD Atlas, we provide the users with a commentary (Figure 1f) that provides a description of the data currently being mapped, a summary of what the key patterns in the map are, and a selection of questions that these maps prompt. For example, as triple therapy among all persons is part of the gender strata in the Atlas, we prompt users to consider why more men than women are dispensed triple therapy, what the user’s DHB can do to address this difference and what can be done to improve dispensing in CVD patients in the user’s cardiac network region.

Separate commentaries were prepared for each therapy/demographic combination and will refresh, for example when users change the display from triple therapy among all persons to triple therapy among Māori.

Additional functionality in the standard template include a Data button (Figure 1g) to toggle the display between the Data Explorer and a pie graph that allows users to select a wedge of data, which updates the display on the map and bar graph.

Whereas the Methodology button (Figure 1h) provides users with a PDF document describing our methodology, the User Guide button (Figure 1i) links to the HQSC website and the generic information regarding the atlas.

Whilst DHB-level variations can be displayed separately for any therapy/demography sub-group in the cohort, these cannot be displayed simultaneously. As a result, this display facilitates an understanding of the variation between regions for that particular
therapy/demography group, but not a comparison according to other demographic parameters e.g. Māori vs. European, young vs. old, men vs. women.

In addition, because the standard deviations are derived for the therapy/demography sub-group of interest they cannot be used to make statistical comparisons with dispensing in other sub groups, and the use of standard deviations to show variability, whilst useful to understand statistically significant regional variation, does not emphasize the absolute magnitude of this variation, or how far from ideal targets each DHB is.

**Advanced template format maps**—An important aspect of this project was to engage with the sector to obtain feedback from our target audience. The stakeholder feedback (reported in detail in the accompanying paper by Grey et al.,) noted some limitations of the standard template, including the inability to simultaneously visualise variability across demographic parameters beyond just DHB of residence, and use of the standard deviation classification approach which does not allow users to easily draw comparisons between all age/gender/ethnic groups for a particular DHB or cardiac network region. To address these concerns we developed the ‘Advanced’ template.

Figure 1. Screenshot of the 'Standard' template, displaying the geography of triple therapy medication dispensing by DHB. This template is available at http://www.hqsc.govt.nz/assets/Health-Quality-Evaluation/CVD_standard/atlas.html

Figure 2 demonstrates the configuration of our advanced template, using geographical variations in triple therapy dispensing among the population aged 60-69 years as an example. The Atlas is available for interactive evaluation at the HQSC’s website:
While the functionality of the Data Explorer and bar graph in the advanced template are identical to those in the standard template, a number of modifications were made following stakeholder feedback to improve interpretation of the patterns.

First, we implemented the ‘heat-map’ legend (Figure 2a), which described variation using four groups ($\leq 55\%$, $56-65\%$, $66-75\%$ and $>75\%$) and is consistently applied across each drug therapy or demographic characteristic the user selects.

The legend also includes an option for users to display the outline of the four National Cardiac Network regions, but all data remains mapped at the DHB level. The location of the Chatham Islands was moved from its correct locality (some 700 km off the east coast of the South Island) to an inset close to Hawkes Bay DHB (the DHB to which these islands belong). This enabled a more compact DHB map displayed at a larger map scale than the standard template (Figure 2b).

To facilitate the comparison of variability between gender, age and ethnic groups more easily we included the radar plot to provide a summary of triple therapy medication dispensing proportions (or each medication class separately) for each demographic group for one or more selected DHBs. For example, Figure 2c shows demographic variations in medication dispensing for the Northland (purple) and West Coast (blue) DHBs, in addition to the national levels (red).

Overall, the West Coast DHB has slightly higher levels of medications dispensed than both the Northland DHB and the national average for the total population, males, females, each age group, Māori and European/other ethnic groups. However, the radar plot highlights the low numbers of Pacific, Indian and Other Asian ethnicities in the West Coast DHB area.

By contrast, with the exception of the Indian population, the Northland DHB has dispensing proportions consistently lower than the national average. Another pattern evident from the radar plot is the low proportion of the population aged 30-39 years consistently dispensed triple therapy.

While Figure 2c compares the selected DHBs with national dispensing patterns, users can choose relevant Cardiac Network regions for comparison, from the comparison area box (Figure 2d). Furthermore, we have also included the ability to filter the map display (Figure 2e), radar plot and bar graph by cardiac network region (Figure 2f) for a more focused analysis of the regional variations.

In the advanced template we maximised the area dedicated to the geographic map and radar plot at the expense of the table and commentary that were included in the standard template. However, we have included these elements as buttons so the display can toggle between the radar plot and the table (Figure 2f) and the commentary (Figure 2g). Users also have access to the HQSC Atlas help pages (Figure 2h).
Figure 2 Screenshot of the 'Advanced' template, displaying the geography of triple therapy medication dispensing among the population aged 60–69 years by DHB. This template is available at http://www.hqsc.govt.nz/assets/Health-Quality-Evaluation/CVD_advanced2/atlas.html

Discussion

This study is the first in New Zealand to examine the geographical variations in CVD medication patterns, particularly in relation to national CVD guidelines. The online Atlas is available in an interactive format that can inform clinicians, policy makers and the public.

We stress that the HQSC’s vision for the Atlas of Variation project is NOT to create league tables that rank the performance of DHBs for a particular health outcome. Rather, the Atlas aims to highlight healthcare variations in a manner that provides benchmarks for other DHBs, and potentially provide an opportunity for others to gain knowledge related to best practice.

While the Standard layouts readily provide users with maps of medication dispensing for different health determinants, the radar plots in the Advanced layouts provide a multi-determinant perspective of different medication adherence trends within and between DHBs. The development of CVD indicators were dependent on the availability and completeness of routine health databases and the ability to link these databases using an individual’s encrypted national health identifier (NHI) to follow their cardiovascular health interactions with primary and secondary care providers.

The accuracy of our analysis is limited by the precision of data in the national health datasets, and while over 98% of the population are identifiable using the NHI, the inclusion criteria for this study may be subject to misclassification error. We defined
our cohort according to patients hospitalised for (and who survived) an atherosclerotic CVD event between 2000 and 2010, while the dispensing patterns relate to 2011.

We excluded events such as unstable angina and Transient Ischaemic Attacks (TIAs), where the diagnosis may not be as certain and so CVD triple therapy is less clearly indicated and we have not captured diagnoses made in primary care, or by private providers, or overseas. In addition, our definition of consistently being on medication refers to a patient being dispensed medication in at least three of the four calendar quarters in 2011, and does not capture the purchase of medications (e.g. aspirin) over the counter. However, we acknowledge that dispensed medication is not a direct indicator of whether a patient actually takes medication daily.

Socioeconomic position is undoubtedly a key determinant of CVD health and a small-area measure of deprivation (NZDep2006) was included in our dataset, but excluded from the Atlas because there was considerable heterogeneity within large administrative districts such as DHBs and the National Cardiac Network regions.

We used InstantAtlas™ to develop our online atlas, which facilitates an effective web mapping solution for developers not proficient in specific GIS software. The Flash-based software creates templates of data that users can investigate, and the presentation of our results in the Standard Layouts is comparable to layouts used in the NHS Atlas of Variation for England.3

At present, we provide users with maps of medication dispensing for one variable at a time (e.g. one age, gender, or ethnic group) and although the software can display data for many strata and variables in the radar plots, grouping data by two variables such as ethnicity and age (e.g. Māori aged 60-69) for mapping geographically would have resulted in small sample sizes and produced unstable estimates of dispensing, particularly in the less populated DHBs.

The configuration of our standard template may be misleading, especially if users do not recognise that the dispensing patterns for one group (e.g. Māori) may be quite different to another (e.g. Indians). Using the standard deviation method to map these variables will ultimately result in the data being presented using the same colour-ramp (light-grey to dark blue), even though the range of values observed for the Māori and Indian populations differs substantially.

As the proportions of medication dispensing are so different between some population strata, we do not recommend comparing maps in the Standard Template atlas, but the advanced template’s fixed legend overcomes this limitation. A further limitation of this study is that our configuration of the Atlas restricts users from interrogating the data for different geographical scales or for sub-populations, such as Māori aged 50-69 years, which is a particular strength of the Dartmouth Atlas.2

This research provides a benchmark against which clinicians and other health care professionals can measure DHB or National Cardiac Regional performance in the future. It is intended that these maps be used as part of quality improvement initiatives to optimise CVD secondary prevention in New Zealand. Future maps will provide time series analyses of dispensing performance over time to track change.

Research investigating unwarranted variations in effective care requires comprehensive patient-level risk factor and outcome data. Our research was only

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possible due to the completeness of the National Health Identifiers maintained by the Ministry of Health. Further improvements to these data, such as improving access to electronic health records will enable the development of further atlases of unwarranted variation in healthcare.

**Competing interests:** Nil.

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