Application of Geographic Modeling Techniques to Quantify Spatial Access to Health Services Before and After an Acute Cardiac Event: The Cardiac ARIA Project

Running title: Clark et al.; The cardiac ARIA project

Robyn A. Clark, PhD, FRCNA1; Neil Coffee, BA(Hons)Geog, MA2; Dorothy Turner, BSc(Geog), PhD3; Kerena A. Eckert, MPH, PhD4; Deborah van Gaans, BSc(Geog)5; David Wilkinson, MD, FRACGP6; Simon Stewart, PhD, FAHA7; Andrew M. Tonkin, MD, FRACP8 on behalf of the Cardiac-ARIA project group

1School of Nursing and Institute of Health & Biomedical Innovation (IBHI) Queensland University of Technology, Queensland; 2Social Epidemiology & Evaluation Research Sansom Institute, Division of Health Sciences, Adelaide; 3GIS and Environmental Modeling School of Earth & Environmental Sciences; 4Population Research and Outcomes Studies (PROS), Discipline of Medicine; 5Dept of Geographical & Environmental Studies, The University of Adelaide, Adelaide; 6Head, School of Medicine, University of Queensland, Queensland; 7Head, Preventative Health, Group Leader Population Health & Profiling, Baker IDI Heart and Diabetes Institute, Adelaide; 8Head, Cardiovascular Research Unit, Dept of Epidemiology & Preventive Medicine, Monash University, Melbourne, Australia

Correspondence:
Robyn A. Clark PhD, FRCNA
School of Nursing and Institute of Health & Biomedical Innovation (IBHI) Queensland University of Technology Kelvin Grove, QLD, 4059, Australia
Tel: +617 31383875
Fax: +617 313814
Email: ra.clark@qut.edu.au

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**Abstract:**

**Background** - Access to cardiac services is essential for appropriate implementation of evidence-based therapies to improve outcomes. The Cardiac Accessibility and Remoteness Index for Australia (Cardiac ARIA) aimed to derive an objective, geographic measure reflecting access to cardiac services.

**Methods and Results** - An expert panel defined an evidence-based clinical pathway. Using Geographic Information Systems (GIS), a numeric/alpha index was developed at two points along the continuum of care. The acute category (numeric) measured the time from the emergency call to arrival at an appropriate medical facility via road ambulance. The aftercare category (alpha) measured access to four basic services (family doctor, pharmacy, cardiac rehabilitation, and pathology services) when a patient returned to their community. The numeric index ranged from 1 (access to principle referral center with cardiac catheterization service ≤ 1 hour) to 8 (no ambulance service, > 3 hours to medical facility, air transport required). The alphabetic index ranged from A (all 4 services available within 1 hour drive-time) to E (no services available within 1 hour). 13.9 million (71%) Australians resided within Cardiac ARIA 1A locations (hospital with cardiac catheterization laboratory and all aftercare within 1 hour). Those outside Cardiac 1A were over-represented by people aged over 65 years (32%) and Indigenous people (60%).

**Conclusions** - The Cardiac ARIA index demonstrated substantial inequity in access to cardiac services in Australia. This methodology can be used to inform cardiology health service planning and the methodology could be applied to other common disease states within other regions of the world.

**Key words:** access; cardiac; healthcare services; Geographic Information Systems (GIS)
Introduction

In an acute cardiac event (cardiac arrest, acute coronary syndrome, acute decompensating heart failure or life-threatening arrhythmias) the time to care is critical. For those who survive, access to basic healthcare services such as a cardiologist or a primary care physician, nursing, pharmacist, pathology services, and cardiac rehabilitation are essential for optimal prevention of a potentially fatal further event.\(^1\) Evidence-based guidelines are available on how to appropriately manage a cardiac event,\(^2\)-\(^{13}\) but their implementation is often greatly influenced by the geographic location and the level of facilities available within a community and the hospital to which a patient initially presents.\(^14\) Although therapies such as defibrillation and thrombolytic drugs are widely available, only an estimated 20% of emergency care departments in the United States,\(^{15,16}\) and less than 7% in Australia\(^{17,18}\) are located in hospitals with a cardiac catheterization laboratory and still fewer hospitals have the capability to perform immediate percutaneous coronary intervention (PCI) or coronary artery bypass grafting.\(^{18}\)

The continuum of care following a cardiac event does not end at hospital discharge. Health care services that support cardiac rehabilitation and ongoing secondary prevention are essential when a patient returns to their community.\(^{11,19}\) Long-term cardiac outcomes will also be strongly linked to the social determinants of health within a community.\(^{19,20}\) Recent data from Sweden have shown that the relative contribution of out-of-hospital deaths has increased, particularly in younger individuals and 90% of all deaths associated with an acute coronary event occurred out-of-hospital.\(^{21}\)

Together with significant health inequalities, inequalities also exist in the access to and the delivery of healthcare services in Australia.\(^{22}\) This is particularly evident for specialist cardiac services in the outer urban fringes and rural and remote areas, where few cardiologists
live and work, and a large proportion of the provision of health care falls upon the local family physician.\textsuperscript{23} With the trend to down grade small town hospitals to nursing homes and aged care centers, or close them down completely, there is an increasing need for rural and remote CVD patients to travel, often long distances, to city based specialist cardiac care centers.\textsuperscript{23} Given that CVD patients consume more health dollars than the average Australian\textsuperscript{24} the added financial costs associated with transport imposes a significant burden.\textsuperscript{24}

In contrast, in recent years, the healthy aging of Australia’s older population has resulted in significant retirement migration from metropolitan and non-metropolitan areas (in 65 years and over age group) and a blurring of the boundaries once drawn around major cities and rural areas. Population growth in non-metropolitan areas has been variable with growth in more accessible geographical locations such as the urban fringes and the rural areas favored by retirees while more remote areas are in decline.\textsuperscript{25} Regrettably, services in these areas, including health services have not kept pace with the changing face of Australia’s non-metropolitan population. Some communities, situated in the fringes of major cities are located between 50-80 kilometers away from the central business districts of major cities.\textsuperscript{25}

There is also clear evidence to suggest that inequities in health outcomes exist between socio-economically advantaged and disadvantaged groups.\textsuperscript{20,22} The gap is widening and poor CVD outcomes are not equally shared across the entire population.\textsuperscript{22} People from socio-economically disadvantaged groups have a poorer risk profile and are more likely to die from CVD than those from more privileged backgrounds.\textsuperscript{22} One of the most disadvantaged groups in Australia are the Aboriginal and Torres Strait Islander people who experience a 2.6 fold greater risk of CVD mortality and a 1.4 higher rate of overall hospitalization. Importantly 41% of all CVD deaths and 30% of deaths occur in Indigenous people living in rural and remote areas of
Australia.26

The Cardiac Accessibility and Remoteness Index of Australia (Cardiac ARIA) was designed to measure access to cardiac care using a geographic lens. Geographic Information Systems (GIS) is software that provides a tool for integrating otherwise unrelated data and to allow inferences about the relationship between these data in a spatial context.27,28 The project was a novel application of GIS which aimed to develop an objective, comparable measure of the time and distance from any population location to evidence-based cardiac care.

Australia, like the United States, is one of the most urbanized countries in the world, with 89% of its total population living in cities. Australia is the world's smallest continent but the sixth largest country (by geographical area). The majority of the population (approximately 22 million) dwells along the eastern and southeastern coasts.29 Australia has a universal healthcare system similar to the United Kingdom that is operated by the federal government authority, Medicare Australia.30 Ambulance services are administered by a state-based system and include professional and volunteer emergency care providers.30

Methods

Design

To meet the project objectives this study was conducted in three phases: an expert panel consensus process, national data acquisition and GIS modeling and a comparison between the index categories and key census population characteristics.

Phase 1: Expert panel consensus process

An expert panel of cardiologists and other key health practitioners (see acknowledgements) utilized a consensus method to define an acute cardiac event and the context of the project
(management before and after hospitalization). The context of this study did not include any acute coronary care after arrival in hospital (e.g., door-to-needle or to balloon time). The panel distilled current national and international guidelines relating to the management of a cardiac event\textsuperscript{2-13} into a single patient care pathway, and from this, a master list of healthcare resources and services was derived.

**Phase 2: Defining Accessibility, Data acquisition and GIS modeling**

A detailed geographic methodology paper has been published elsewhere and the full project report is available on-line at www.qut.edu.au/research/cardiac-aria.\textsuperscript{31} The following is a summary of the GIS accessibility modeling used in this project.

**Defining Accessibility**

Access is an important concept in health policy and health services research, but often not defined or applied consistently. Accessibility can be defined as ‘the ease of approach from one location to another measured in terms of distance travelled, the cost of travel, or the time taken’. Remoteness can be defined as ‘distant or far away geographically’.\textsuperscript{32} These concepts are at the heart of geographic models of access and remoteness, the underlying principle of which is the impact that distance plays in assisting or hampering access to goods and services or in this case, access to cardiac healthcare services. We acknowledge that these definitions refer to physical rather than social accessibility, which could include class structure, income, age, education, gender or ethnicity, and the impact these factors can have in accessing services.\textsuperscript{32}

Remoteness, has been calculated in this project on the basis of accessibility to service centers based on road distances and was modeled on the Accessibility and Remoteness Index Australia (ARIA).\textsuperscript{33} ARIA was designed to be simple, comprehensive, sufficiently detailed, transparent, defensible and stable over time. Because ARIA was also designed to be an
unambiguously geographical approach to defining remoteness, socioeconomic, urban/rural and population size factors were not incorporated into the measure. ARIA used ESRI spatial Analyst to construct accessibility raster cost distance surfaces along and away from the road network to represent a distance measure for all of Australia. By combining the accessibility layers using the ESRI raster calculator, a single value was calculated for each population center in Australia. To develop the Cardiac ARIA model this methodology was adapted and modified to include cardiac evidence-based time calculations as well as distance. The ARIA classification has been widely accepted by a variety of users since its release in 1999. As a result, the Australian Bureau of Statistics (ABS) included ARIA scores as part of the 2001–2006 Census data releases.

**Data acquisition and modeling**

From the master list of health care resources and services for the management of a cardiac event, nine key spatial and clinical datasets were used to model Cardiac ARIA. These data included road networks, population centers, ambulance stations, hospitals and remote area clinics, primary care physicians, pharmacies, cardiac rehabilitation programs and pathology laboratories. The road network and population centers data were sourced from Pitney Bowes Business Insight and represent two of the key data sets in the model. Ambulance station location data were sourced from each state or territory jurisdiction and included metropolitan, rural and remote services. The location data of public hospitals was sourced from the Commonwealth Department of Health and Aging and remote area clinics from the National Aboriginal Community Controlled Health Organization (NACCHO). A national classification (The Australian Institute of Health and Welfare (AIHW) Public Hospital Peer Groups’ classification) was used to categorize medical facilities/hospitals into broadly similar groups in
terms of the range of admitted patient activity and their geographical location. From this classification of public hospitals, five categories of medical facilities/hospitals were modeled based on diminishing levels of access to cardiac services and increasing remoteness (Table 1). The 44 hospitals included in the Cardiac ARIA category 1 have cardiac catheterization services, however Percutaneous Cardiac Interventions (PCI) were not available twenty four hours/seven days a week in all, and not all cardiac catheterization centers have a co-located cardiothoracic surgery service.\textsuperscript{18} Data on the location of primary care clinics, community health clinics, pharmacies and pathology services was sourced for the aftercare model. The National Association of Testing Authorities’ dataset (NATA) was used to identify pathology services.\textsuperscript{37} Cardiac rehabilitation programs were acquired from the Australian Cardiovascular Health & Rehabilitation Association (ACRA).\textsuperscript{38} To differentiate urban from non-urban areas for modeling travel speeds, ABS data on urban center locations were extracted from the ABS census area database.\textsuperscript{39} The GIS software applications used for this project were ESRI Arc Map, version 9.3.1 and spatial analyst (ESRI 2009, Redlands, CA, USA).\textsuperscript{34}

The Cardiac ARIA Index is presented as a two part numeric/alphabetic categorization. The numeric category rates accessibility to services after an acute cardiac event, and the alphabetic category of the index rates accessibility to the services required for care after an acute cardiac event when the patient returns to their community. GIS measured the times to these services for each of the 20,387 population locations.

The measurements were calculated from the central point of each population area using the minimum bounding rectangle method; for each population location the smallest possible rectangle is used to enclose the location and the central point identified and used to estimate distance. Time classifications were soundly based on previous studies in time modeling to
cardiac services\textsuperscript{16,40-42} and upon current international and national evidence-based timeframes for the management of an acute cardiac event\textsuperscript{2-13,43}. As the majority of acute cardiac events are managed in Australia by road ambulance or mobile Intensive Care Units\textsuperscript{42} Cardiac ARIA is a time-based accessibility model, which measured access to the highest level of available medical assistance by road (Cardiac ARIA “Acute” model). For management after discharge of an acute cardiac event (Cardiac ARIA “Aftercare” model), drive time by private car was modeled along the road network.

Iterative modelling conducted prior to the model reported in this paper did not appreciably change our results and the final iteration was considered the most robust in real world practice.\textsuperscript{2-13} Sensitivity testing of eight timeframe radii to services and re-routing to PCI were tested. The major difference in the models was the break points and not the speeds. The fundamental concept of the final model was the “average” position based upon clinical guidelines and published average travel times. The outcomes of these sensitivity analyses indicated that most Australians (66% -73%) will meet the 1 hour access to PCI facilities. While we have looked at sensitivity by ten percent time variations the situation did not change the outcomes significantly. The issue of good access decreased by less than 1% variation, and poor access remained relatively unchanged because these locations were not densely populated.\textsuperscript{31} We made the decision to focus on the clinical timeline and reported average times\textsuperscript{31} to provide an outcome that reflected a result that was a reasonable guide for policy. Clearly, travel times will differ due to time of day and weather, but the purpose of this modeling was to provide a view of reality that would have utility in guiding health policy and allocation of resources.

Acute Cardiac ARIA was modeled to the best available medical facility within one hour by road ambulance.\textsuperscript{43} Each Acute Cardiac ARIA time calculation included dispatch time (3
minutes), travel time to location (15 minutes urban and 19 minutes rural), time on site (15 minutes) and travel time to the nearest and best medical facility within 60 minutes. Urban road speeds were calculated at 40kph (25mph), non-urban road speeds at 80kph (50mph), and unsealed road speeds at 50kph (31mph).\textsuperscript{42-43} Acute Cardiac ARIA category 1 represents a population center within one hours access to a principal referral hospital with a cardiac catheterization laboratory; category 2 represents access to a principal referral hospital without a cardiac catheterization laboratory within one hour, through to a category 5 which represents 1 hour access to a level 5 hospital/medical clinic. Category 6 was between one to three hours to any medical facility, Category 7 (30 minutes transport by private car) was created to model the many remote clinics without access to an ambulance service and category 8 was more than three hours from any ambulance or medical facility. (Table 1 and Figure 1)

The Cardiac ARIA (Aftercare) alphabetic category measured access within one hour drive time from population locations along the road network to key services (Figure 1). The list of key services was based on a hierarchy developed by the cardiac rehabilitation experts from our expert panel. These were prioritized as access to medical follow-up (Primary care physician), access to pharmacy, access to a cardiac rehabilitation program, and access to pathology services.

The GIS modeling was based on research that indicated that compliance diminished as access to these services increased beyond one hour drive time.\textsuperscript{44} Category A represented one hour access to all four services, decreasing in a hierarchy of accessibility to Category E; no services within one hour. (Figure 1)

**Phase 3: Comparison of Cardiac ARIA categories and key census population characteristics**

The ABS Census of Population and Housing was used to provide population data for Cardiac
ARIA scores. The population census characteristics reviewed were total persons in each Cardiac ARIA category, persons aged 65 years and over and the proportion of persons self-identified as Aboriginal and Torres Strait Islanders and remoteness. Microsoft Excel 2007 and ArcGIS were used to summarize the selected population variables as number and percentages for each ARIA and Cardiac ARIA score. GIS was used to create a spatial link between the Cardiac ARIA score and each census collection district (CD) similar to a census tract in the US.

**Ethics**

Ethics approval for this project was provided by the Human Research Ethics Committee of the University of South Australia approval number P136/09.

**Results**

The Cardiac ARIA index combined the eight categories (1-8) of acute access and the five aftercare categories (A-E) to form a numeric-alpha value (potentially 1A-8E) for each population location. (Figure 1) However, when the GIS calculations were completed, only 19 of a possible 40 index combinations were needed to describe accessibility for each of the 20,387 population locations. (Figure 1)

The geographic distribution and the range of the numeric/alpha combinations are shown in Figure 2.

**Access to acute cardiac services**

In the event of a cardiac emergency, the majority of Australians had good access to cardiac services. Approximately 71% (13.9 million people) and 68% of all and older Australians (> 65 years), respectively, resided within one hour of a category 1 hospital. Ninety thousand people
over 65 years (4% of 65 year old population) lived more than one hour from any hospital or clinic (categories 6, 7, and 8). Only 40% of Aboriginal and Torres Strait Islander people lived within one hour of a category 1 hospital and 16% (74,000 persons) resided in locations with poor access to any medical assistance (categories 6, 7 and 8).

**Access to cardiac services after a cardiac event**

Approximately 96% of Australians (19 million people) and 96% of those aged >65 years lived within one hour of the four key services to support cardiac rehabilitation and secondary prevention. Seventy five percent of Indigenous people lived within one hour of the four cardiac rehabilitation services and 16% (73,000 persons) had poor access to the four key services to support cardiac rehabilitation and secondary prevention (categories D and E).

**Access to cardiac services before and after a cardiac event**

Eighteen percent of Australian population locations were situated in the combined cardiac aria category 1A zones (access to a principal referral hospital with a cardiac catheterization laboratory and all aftercare services within one hour) indicating that 82% of population locations in Australia had greater than one hour access to recommended cardiac care. Figure 3 demonstrates that there was a high proportion of localities in several categories other than 1A including; Category 4A (9%) (<1 hour to a medium size hospital/ no PCI capability, < 1 hour to all aftercare services); Category 5A (12%) (<1 hour to a small hospital or clinic /no PCI; < 1 hour to all aftercare services), 6A (16%) (1-3 hours to any hospital or clinic/no PCI; < 1 hour to all aftercare services) and 8E (5%) (no ambulance service, > 3 hours to any medical center; no aftercare services). (Figure 3) Based on the analysis of each of the Cardiac ARIA categories, it was estimated that approximately 71% or 13.9 million Australians resided within category 1A locations (access to a principal referral hospital with a cardiac catheterization laboratory and all
aftercare services within one hour), including 68% of older Australians (> 65 years) and 40% of Aboriginal and Torres Strait Islander people. Conversely, 12% (56,000) of Aboriginal and Torres Strait Islander people resided in locations with poor access to a hospital or medical center, and had access to only one (usually a doctor or clinic) or none of the four key aftercare services (categories 6D to 8E). (Table 2)

Discussion
Cardiac ARIA, derived from an innovative model using GIS technology, describes the access to cardiac healthcare services relative to the geographic dispersion of a country’s population. Based on recent census data, approximately 71% lived within a Cardiac ARIA index category 1A location (access by road to a principal referral hospital with a cardiac catheterization laboratory and to all aftercare services within one hour). Access to appropriate rehabilitation services was higher (91%) than for acute services (71%), and older and Indigenous people who carry a higher burden of disease than the general population were more disadvantaged in terms of access.

A recent study using GIS in the US has demonstrated that nearly 80% of the adult population in the United States lived within 60 minutes of a PCI hospital in 2000. Even among those living closer to non-PCI hospitals, almost three quarters of the population would experience an additional delay of less than 30 minutes with direct referral to a PCI hospital, which suggested that such a strategy might be feasible for these individuals. These results indicate a greater percent of initial access to PCI than modeled for Australia in Cardiac ARIA and a re-routing model is planned for future iterations. A review of access to general cardiac services in Kentucky’s which reported on the spatial statistical comparison of the geographical distribution with service usage and travel time to hospitals showed that people living in rural
areas travelled further to services; and that populations residing more than 45 minutes from health facilities were more likely to be socially and economically marginalized.\textsuperscript{47}

Another Australian study which used simple Google maps to measure access to PCI was consistent with our results, demonstrating that 78\% of Australian cardiac catheterization laboratories were located in major cities and that a significant number of Australians could not access PCI within the timeframes recommended in guidelines.\textsuperscript{2-13,17} The findings in our study reflect the size and nature of the Australian continent, in which it appears that, access to cardiac services may represent an all-or-nothing situation, with almost one third of the population (29\%) outside of the road distance (and time frame) for primary cardiac intervention. \textbf{Figure 4} shows that there were time “zones” of accessibility.

These findings can directly inform strategies to improve outcomes for cardiac patients. For locations in which access is limited there could be an agreed plan for mobilization and synchronization of appropriate services to optimize timely access to evidence-based care such as PCI.\textsuperscript{48} The speed with which the system mobilizes (or response time) may be as important as distance when determining the outcomes after a cardiac event.\textsuperscript{49-50}

Similar to the US, the current uptake of cardiac rehabilitation and secondary prevention programs by eligible cardiac patients in Australia is between 10 and 47\%.\textsuperscript{51-52} This is despite the fact that our study showed that the majority of Australians had excellent “geographic” access to cardiac rehabilitation and secondary prevention programs after discharge following a cardiac event. Therefore, it appears that it is not the distance to cardiac rehabilitation that is affecting attendance.

We would recommend that population locations, with limited access to cardiac services could benefit from a nationally coordinated, virtual or electronically supported cardiac care
system and the development of innovative clinical approaches to improve access to reperfusion and other therapies, point-of-care testing and cardiac rehabilitation. This requires co-ordination across state boundaries and health jurisdictions. The Cardiac ARIA Index focused on community access, and communities themselves could be proactive in lobbying for improving access to cardiac care.

Where Cardiac ARIA is unique, is that no previous research has measured accessibility to cardiac services with a model which included essential services prior to hospitalization or produced an output in the form of a weighting or index. The index provides a variable that can be used in statistical modeling to measure the impact of access on cardiac outcomes and the requirements for the most rational situating of cardiac services.

Our model can be easily replicated. It used common internationally available geographic software (ESRI Arc Map, version 9.3.1 and spatial analyst) and was modeled with data that was publically available. The methodology underlying Cardiac ARIA could be readily adapted to other emergency or chronic conditions (e.g., access to specialist care for stroke, diabetes, chronic obstructive pulmonary disease, bronchial asthma, burns, cancer and mental health care) in any country where the software and similar location and healthcare service data is available and can be accessed.

The Cardiac ARIA index has some limitations. Its validity is dependent of the quality of the data that were acquired. Accessing national datasets was both a major achievement and burden within this project. The index will be iterative as data is updated and access to key national datasets improves. A validation of the index using CVD risk factor data and disease outcomes is currently in progress.
Conclusions

The Cardiac ARIA project was underpinned by a novel partnership between clinicians and geographers. The research generated an objective geographic measure of access to health services independent of cultural, socio-economic, physician judgment or health politics. This allowed demonstration of substantial inequities in access to cardiac services for major at-risk groups within Australia. Cardiac ARIA represents a powerful tool that could be used by communities, clinicians, researchers and healthcare funders to inform improved health strategies and to optimize cardiac outcomes.

Acknowledgments: The Cardiac ARIA Team wishes to acknowledge all contributors to this project including those who helped to conceptualize this project from the beginning. The contributors listed below have given permission to be named individually. Mr. Peter Astles, a passionate advocate of geography in health is acknowledged for establishing the partnership for the linkage funding. We wish to especially thank David McDonald, Spatial Services Manager, (PBS Partner), Nigel Lester, Commercial Sales Manager, Dave Ng, Channel Sales Executive, Paul Parson, Contracts Manager, from Australia & New Zealand, Pitney Bowes Business Insight, for supporting the project by providing strategic datasets such as Tonkin Street Pro. The project acknowledges the contribution to Cardiac ARIA from all collaborators and team members including Prof Graeme Hugo, Ms Maria Fugaro, A/Prof Annette Raynor, Chris Moylan, Prof Mark Daniel, Jacqui Howard, and our expert panelists: Professor Derek Chew, Professor Hugh Grantham, Professor Peter Thompson, Professor Phil Tideman, Rosy Tirimacco and The Heart Foundation (Australia) Vanessa Poulsen and Wendy Keech. We also acknowledge the QUT School of Nursing writers retreat organizers Professors Patsy Yates and Deb Anderson.

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Conflict of Interest Disclosures: None

Web Appendix: The Cardiac ARIA Index http://www.qut.edu.au/research/cardiac-aria
References:


40. Bamford EJ, Dunne L, Taylor DS, Symon BS, Hugo GJ, Wilkinson D. Accessibility to


### Table 1: Cardiac ARIA hospital categories

<table>
<thead>
<tr>
<th>Cardiac ARIA Hospital Category</th>
<th>Hospital categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Principal Referral with Catheter Laboratory</td>
<td>Principal Referral</td>
</tr>
<tr>
<td>2 - Principal Referral without Catheter Laboratory</td>
<td>Principal Referral</td>
</tr>
<tr>
<td>3 - Large</td>
<td>Large Hospital, Major city</td>
</tr>
<tr>
<td></td>
<td>Large Hospital, Regional and Remote Area</td>
</tr>
<tr>
<td>4 - Medium</td>
<td>Medium Hospital, Regional and Remote Area</td>
</tr>
<tr>
<td>5 - Other</td>
<td>Small Acute Hospitals, Regional</td>
</tr>
<tr>
<td></td>
<td>Small Non-Acute Hospitals</td>
</tr>
<tr>
<td></td>
<td>Small Acute Hospitals, Remote</td>
</tr>
<tr>
<td></td>
<td>Multi-purpose Services (MPS)</td>
</tr>
<tr>
<td></td>
<td>Other Remote Clinics</td>
</tr>
</tbody>
</table>


### Table 2: Population characteristics for each Cardiac ARIA category

<table>
<thead>
<tr>
<th>Cardiac ARIA Category</th>
<th>% of Total Population n (%)</th>
<th>% of Total Indigenous Pop n (%)</th>
<th>% of Total Persons Aged &gt;=65 n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>13,983,696 (70.58%)</td>
<td>180,210 (39.74%)</td>
<td>1,784,081 (67.56%)</td>
</tr>
<tr>
<td>2A</td>
<td>1,655,086 (8.30%)</td>
<td>47,821 (10.55%)</td>
<td>230,228 (8.72%)</td>
</tr>
<tr>
<td>3A</td>
<td>1100338 (5.55%)</td>
<td>32252 (7.11%)</td>
<td>172781 (6.54%)</td>
</tr>
<tr>
<td>4A</td>
<td>1127226 (5.69%)</td>
<td>39983 (8.82%)</td>
<td>181727 (6.88%)</td>
</tr>
<tr>
<td>4B</td>
<td>7183 (0.04%)</td>
<td>78 (0.02%)</td>
<td>1058 (0.04%)</td>
</tr>
<tr>
<td>4C</td>
<td>89,497 (0.45%)</td>
<td>2,718 (0.60%)</td>
<td>14,068 (0.53%)</td>
</tr>
<tr>
<td>5A</td>
<td>669,981 (3.38%)</td>
<td>27,182 (5.99%)</td>
<td>107,617 (4.08%)</td>
</tr>
<tr>
<td>5B</td>
<td>101,629 (0.51%)</td>
<td>8,358 (1.84%)</td>
<td>17,680 (0.67%)</td>
</tr>
<tr>
<td>5C</td>
<td>223,851 (1.13%)</td>
<td>23,463 (5.17%)</td>
<td>29,924 (1.1%)</td>
</tr>
<tr>
<td>5D</td>
<td>102,898 (0.52%)</td>
<td>17,191 (3.79%)</td>
<td>7,827 (0.30%)</td>
</tr>
<tr>
<td>6A</td>
<td>486,069 (2.45%)</td>
<td>12,485 (2.75%)</td>
<td>67,266 (2.55%)</td>
</tr>
<tr>
<td>6B</td>
<td>44,293 (0.22%)</td>
<td>2,044 (0.45%)</td>
<td>5,445 (0.21%)</td>
</tr>
<tr>
<td>6C</td>
<td>79,455 (0.40%)</td>
<td>3,103 (0.68%)</td>
<td>9,294 (0.35%)</td>
</tr>
<tr>
<td>6D</td>
<td>40,411 (0.20%)</td>
<td>10,777 (2.38%)</td>
<td>3,090 (0.12%)</td>
</tr>
<tr>
<td>6E</td>
<td>16,139(0.08%)</td>
<td>975 (0.22%)</td>
<td>1,414 (0.05%)</td>
</tr>
<tr>
<td>7D</td>
<td>40,809 (0.21%)</td>
<td>34,219 (7.55%)</td>
<td>1,684 (0.06%)</td>
</tr>
<tr>
<td>8C</td>
<td>2,332 (0.01%)</td>
<td>62 (0.01%)</td>
<td>486 (0.02%)</td>
</tr>
<tr>
<td>8D</td>
<td>3,757 (0.02%)</td>
<td>1,987 (0.44%)</td>
<td>218 (0.01%)</td>
</tr>
<tr>
<td>8E</td>
<td>29,765(0.15%)</td>
<td>8,225 (1.81%)</td>
<td>2,101 (0.08%)</td>
</tr>
<tr>
<td>*NA</td>
<td>18,666 (0.09%)</td>
<td>296 (0.07%)</td>
<td>2,678 (0.10%)</td>
</tr>
<tr>
<td>Total</td>
<td>19,813,080</td>
<td>453,429</td>
<td>2,650,667</td>
</tr>
</tbody>
</table>

*NA= persons off-shore or migratory and therefore not allocated a Cardiac ARIA value.
Figure Legends:

**Figure 1.** Flowchart for numeric and alpha phases of the index (Acute Cardiac Care and Aftercare)

**Figure 2.** Cardiac ARIA categories mapped by location

**Figure 3.** Proportion of population locations and regional classification for each Cardiac ARIA category

**Figure 4.** Cardiac ARIA zones of access
Complete Cardiac ARIA Model
Calculated for each of the
20,387 Localities

Cardiac ARIA Acute Index
1. ≤1 hour from category 1 hospital
2. ≤1 hour from category 2 hospital
3. ≤1 hour from category 3 hospital
4. ≤1 hour from category 4 hospital
5. ≤1 hour from category 5 hospital or clinic
6. 1-3 hours from any hospital or clinic
7. ≤30 minutes by private transport [No ambulance] from remote clinic
8. >3 hours to any medical facility

Complete Cardiac ARIA Model
*(39 categories not all scenarios represented)*
Acute 1 to 8
Aftercare A to E

Cardiac ARIA Aftercare Index
A. ≤1 hour from GP/Nurse Clinic, Pharmacy, Cardiac Rehabilitation, Pathology.
B. ≤1 hour from GP/Nurse Clinic, Pharmacy, Cardiac Rehabilitation.
C. ≤1 hour from GP/Nurse Clinic, Pharmacy.
D. ≤1 hour from GP/Nurse Clinic.
E. No services within 1 hour by road