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Review

Models used to understand barriers towards Healthcare Access within Australian Health System Context

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Abstract: Understanding the barriers to healthcare access is a multifaceted challenge, which is often highly diverse depending on the location and the prevalent surroundings. The barriers can range from transport accessibility to socio-economic conditions, ethnicity and various patient characteristics. Australia has one of the best healthcare systems in the world, however, there are several concerns on its accessibility, primarily due to the vast geographical area it encompasses. This review study is an attempt to understand the various modelling approaches used by researchers to analyse diverse barriers related to specific disease types and various area distribution of the country. In terms of the barriers, the most affected people are those living in rural and remote parts, and the situation is even worse for the Indigenous people. These models have mostly focussed on the use of statistical models and spatial modelling. The review reveals that most of the focus has been on cancer-related studies and understanding accessibility among rural and urban population. The future work should focus towards further categorising population based on indigeneity, migration status and the use of advanced computational models. This article should not be considered as an exhaustive review of all the aspects as each section deserves a separate review of their own. However, it highlights all the key points covered under several facets which can be used by researchers and policy makers on the current limitations and the steps that needs to be taken to improve health accessibility.

Keywords: Access Barrier; Health Outcome; Model; Review

1. Introduction

The appropriate and timely access to healthcare is of utmost importance, which if not provided can lead to several concerns like missed scheduled appointments, delayed medication, and potential fatality. The barriers to accessibility are varied and are dependent on the location, affected disease and patient characteristics. Australia is a vast country with a very diverse population where settlement is spread thinly over vast areas [1]. In terms of geographic patterns, 31% of the population lives in rural and remote parts, who have lower usage rates due to the distance decay relationship. Distance decay association suggests that people who live farther from healthcare facilities, have lower rates of usage after adjustment of other factors for need, than those who live closer [2]. Also, longer travel times to healthcare facilities may be associated with worse health outcomes for patients [3].

Weinhold and Gurtner [4] in their review article on health services in rural areas found that the rural areas suffer from a limited and inferior quality of health services when compared to urban areas. The delay to healthcare services due to transportation obstacle is a critical issue for patients suffering from fatal injury, necessary check-ups and medication. In such instances, the importance of understanding transportation barriers is more significant than the access itself. The impediment to transportation can also affect the medication of patients and have long-term detrimental health concerns.

The diversity of Australia is quite rich with 2.3% of the population belonging to the Aboriginal and Torres Strait Islander people, who suffer the most in terms of healthcare accessibility. Rolfe et al. [5] highlighted that the most deprived section are the indigenous people, irrespective of any health measure. Apart from the geographical barrier, factors like socio-economic status and cultural bias also seems to be of significance among indigenous people. Li [6] studied the barriers faced by Indigenous people and listed several challenges like cultural difference, linguistic barrier, and economic aspect were highlighted. It also studied the role of healthcare professionals and suggested several measures which could help to overcome the barriers. McBain-Rigg and Veitch [7] conducted a study on the indigenous residing in north-west Queensland by performing interviews with the people and health professionals. The interviews revealed that the focus needs to shift towards building trust and interpersonal relationship among the community and health professionals, and not only improving the physical environments.

This paper is organized in six sections, wherein the first section introduces the need for such a review. Section 2 discusses the various sources used to collect the relevant articles and its bibliographic and geographical analysis. Thereafter, section 3 highlights the definition of accessibility and spatial techniques used to measure it along with the Australian healthcare system and the various barriers being considered to understand accessibility. Section 4 discusses the studies for barriers to accessibility related to various diseases, along with the methodologies used and the results obtained. Consequently, Section 5 discusses the points of strength and highlight the present shortcomings. Finally, Section 6 concludes and summarizes the study.

2. Data Collection

The primary objective behind the review article was to understand the models being studied for barriers related to healthcare access. For this, bibliographic search was conducted on PubMed, Web of Science for peer-reviewed studies written in English and conducted only for Australian context. The search was based on various annotations of keywords, “Barrier*”, “Model*”, “Health Outcome”. Medical Subject Heading (MESH) terms included health services accessibility, barrier, and health outcome. After conducting the relevant searches and removing the duplicates, a total of 127 papers were selected. The distribution of the articles year wise is depicted in Figure 1.

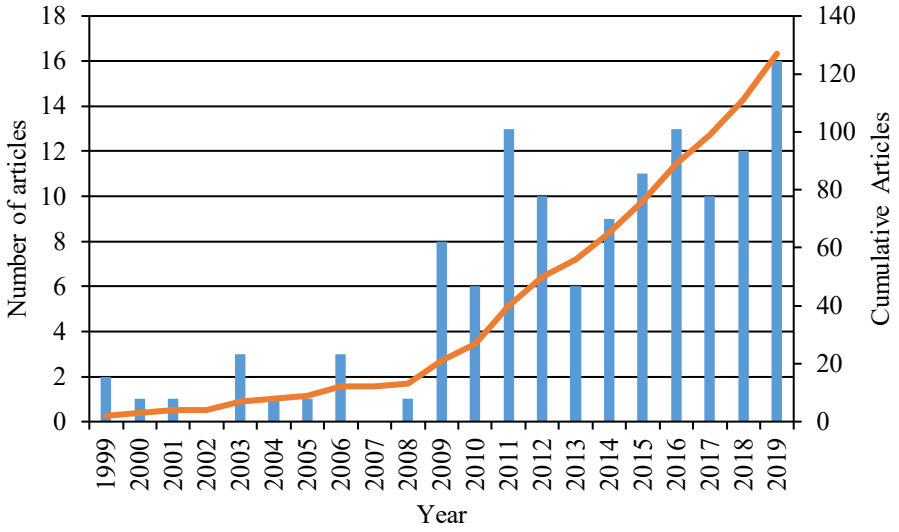

Figure 1. Analysis of the literature database from 1999-November 2019. The left Y axis represents the number of articles per year and right Y axis depicts the cumulative number of articles for the entire period.

The articles were published in 73 different journals, with the most number of publications in Medical Journal of Australia (10%), BMC Health Services Research (5%), Rural and Remote Health (4%), Applied Geography (5%), Australian and New Zealand Journal of Public Health (3%), Australian Journal of Rural Health (4%), Cancer Epidemiology (3%), International Journal of Health Geographics (3%).

We also analyzed the states where the studies were conducted. The results reveal that 20% of the studies were conducted on a national level, whereas the studies conducted across various states are illustrated in Figure 2. The analysis was performed based on the state where the study was conducted irrespective of covering a small part of the state.

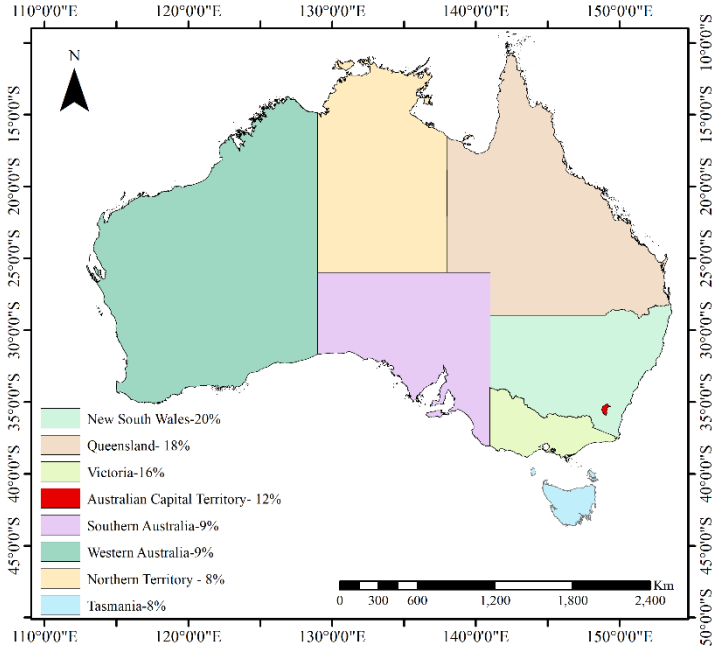

Figure 2. Number of studies conducted across various states of Australia

3. Definition of Accessibility

Health care access has been classified into 5 categories by [8], which are: a) availability b) accessibility/proximity c) affordability d) acceptability e) accommodation. The first two (availability, accessibility) can be considered as spatial whereas the remaining factors are non-spatial [9]. Geographic Information Systems (GIS) is considered as a powerful tool to integrate both spatial and non-spatial factors [10]. However, most of the studies have analyzed hindrance to access under spatial context irrespective of any disease type.

The studies focusing on spatial accessibility has been analyzed using three different techniques: i) distance/time to nearby services ii) gravity models iii) population versus provider services/ doctor-population ratio (DPR) or bed-population ratio (BPR) [11,12]. The first approach is a simple technique wherein the distance between population residence and service provider (proximity) is determined and doesn't consider the availability aspect of spatial accessibility. The determination of accessibility has been usually carried out by determining the travel time. However, some studies have used the line-of-sight measure, in which the distances were used as a measure of access [13-16]. This concept can be used in some scenarios as access to cars is one of the highest in the world for people residing in urban areas of Australia due to a highly developed road network [13]. The second approach considers both the aspects (availability and proximity), however the limitation of using gravity models is the challenge in the determination of distance-decay function [9,17]. The population versus provider services approach uses a classification of population and health services within a defined

region instead of the spatial movement as used in the other two approaches. The determination of the ratios is easy to compute, as the data for both the population and the health centers are usually available. The use of such an approach involves two assumptions: a) population is expected to use health services within the defined region, and b) the proximity aspect is negligible within the region [11]. The significant difference lies in the selection of defined regions. As the name suggests, floating catchment area (FCA) uses floating areas or 'windows' instead of defined regions, the size of which is determined by the availability of the required services within a region. The use of FCA had a major challenge of not considering the demand aspect with respect to the supply-demand concern. This challenge was addressed by [18], in which they introduced the spatial decomposition method, and this approach was then used by [17], who introduced the two-step FCA or 2SFCA method. The 2SFCA method is performed in two steps, first by calculating the size of the population within the catchment, and secondly determining the available services in the catchment.

The accessibility to healthcare is usually conducted using the GIS techniques, which measure the travel distance and time used by the public or private transportation system. The studies can be categorized as Revealed accessibility and Potential Accessibility [3]. Revealed accessibility is the actual time taken to reach health centers whereas potential accessibility analyses the potential to access healthcare determined using either the gravity models or the specialized gravity models like 2SFCA method.

After collecting and determining the relevant health barriers, statistical models were applied to analyze the association of the factors with survivability along with the interrelationship of the barriers. The present review looks at the models used to understand the barriers to healthcare access for various diseases in Australia. The aim is also to analyze the survivability or outcomes in relation to the barriers. The review has been conducted based on several categories including disease, study area, models used, number of patients, rural vs urban, consideration for the Indigenous people, and the dataset (source and time period) used.

3.1. Australian Healthcare System

The Australian health care system is considered as a hybrid model where people can purchase private insurance coverage along with the public insurance they already receive, making it accessible to both public and private hospitals [19]. The vast geographical area of the country, varied residential location and their uneven distribution of population, network of roads and traffic conditions and the allocation of hospital resources leads to the imbalance of health services access for the people [12]. In terms of practicing physicians, Australia has 3.39 per 1000 people, which is one of the highest in the world [19]. It also spends the most on healthcare among the Organization of Economic Cooperation and Development (OECD) countries, which is a consortium of 34 countries dedicated towards developing policies for various social and economic challenges [19]. A detailed understanding of the Australian healthcare system can be found in [20].

It has been well established that following illness, the health outcomes could get worse upon travelling a longer distance to health centres. Similar bias is often visible with residents living in the rural areas as compared to the urban areas. The variation between the survivability among rural and urban residents for various health cases have been analyzed by several studies [21-23]. The rural population suffers from higher fertility and perinatal mortality rate compared to the urban population. The chances of health cases (e.g. diabetes, high cholesterol, cancer, heart disease) is higher than urban population, which lowers their life expectancy by 4 years. The National Rural Health Alliance found that the barriers among remote and major cities are enormous, for example, in case of remote/very remote areas over 58% people reported not having a specialist nearby as compared to only 6% in case of major cities. Such startling differences are also present across different disease type and health visits.

3.2. Factors Considered/Barriers

The geographical classification of the country is based on the Australian Statistical Geography Classification (ASGC) framework provided by Australian Bureau of Statistics (ABS). The

classification was initiated in 2011, prior to it the Australian Statistical Geography Standard (ASGS) classification was used. The studies conducted have determined the geographical location of their respective study region based on census classification which has been modified over years. The population can be either based on place of enumeration (based on the location on census night) or place of usual residence (based on the location where they usually live). The studies related to healthcare access has been conducted based on place of usual residence. Before 2001, the census was based on Statistical Local Area (SLA) which was changed to Collection District (CD) Level in the next census. For 2011 census, the Australian Statistical Geography Standard (ASGS) has been used in which the data is available at SA1 level which could be aggregated to higher spatial scales of geography.

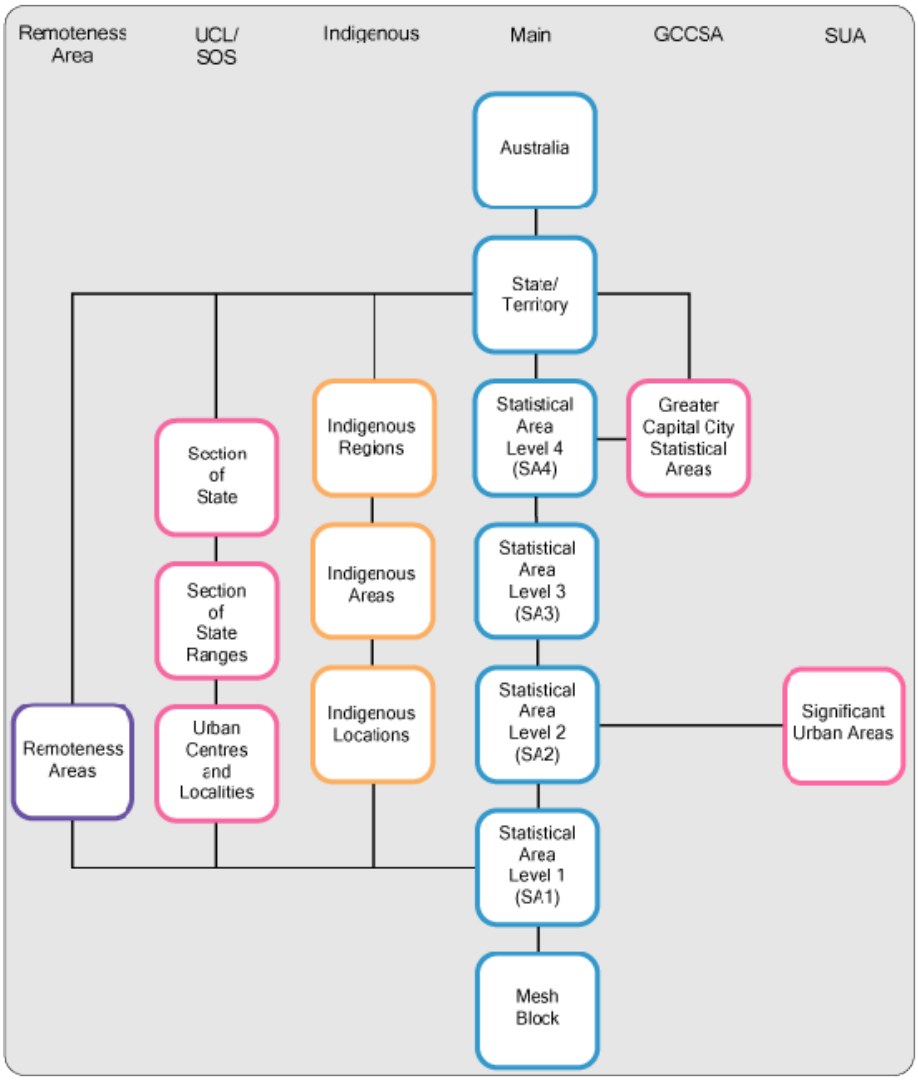

Figure 3. Australian Statistical Geography Standard: Structure (Source: ABS)

The remoteness of a place can be categorized in either of the five classifications: major cities, inner regional, outer regional, remote and very remote [4]. The remoteness has been defined based on ASGC-RA (Remoteness Area) classification. This classification determines the physical distance of a location and allows quantitative comparison between metropolitan and rural regions. To compute ASGC-RA, Accessibility/Remoteness Index of Australia (ARIA+) score is determined. This is an index of remoteness with values ranging from zero (high accessibility) to 15 (high remoteness) based upon the physical distance of a location from the nearest urban centre based on census data of population size [24].

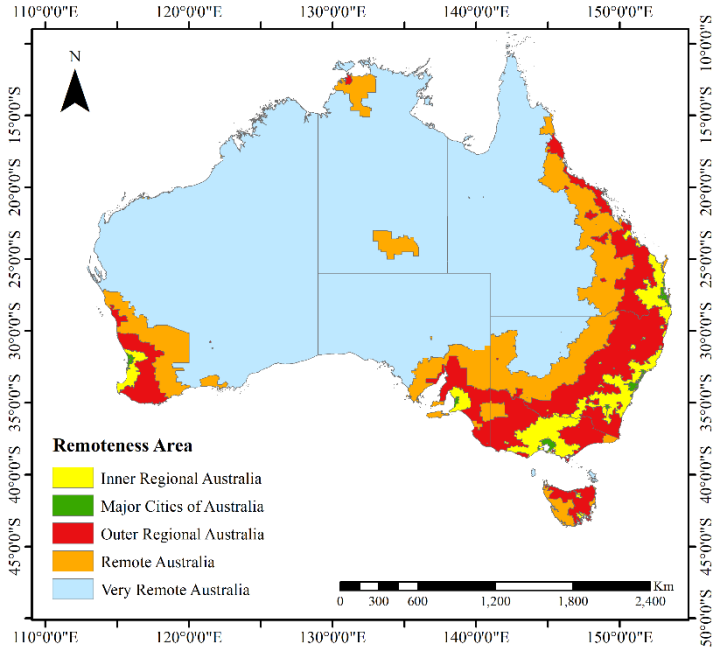

Figure 4. Remoteness map of Australia, 2016 (Source: ABS)

The other critical factor while determining accessibility is the socio-economic status (SES) and is based on the Socio-Economic Index for Areas (SEIFA) developed by Australian Bureau of Statistics (ABS) and is a set of four indexes: The Index of Relative Socio-economic Disadvantage (IRSD); The Index of Relative Socio-economic Advantage and Disadvantage (IRSAD); The Index of Education and Occupation (IEO); and The Index of Economic Resources (IER). SEIFA comprises of five categories which are most disadvantaged; above average disadvantaged; average disadvantage; below average disadvantage and least disadvantage [13]. Generally, socio-economic index is assigned using area-based measurement, which tends to be bias and often inaccurate. This was highlighted by [25] wherein they used the individual-based demographic data and compared the survival disparity when considering LGA and CD classification in New South Wales region. The results highlight the underestimation of survival disparity with little variation when RER is calculated. Factors like patient characteristics include smoking, employment, ethnicity, disability, indigeneity, stigma and discrimination have also been explored by researchers under various circumstances [26,27].

The pandemic of COVID19 has revealed new barriers and challenges to healthcare workers and patients affected by it. This has led to patients with several necessary and critical health conditions to prematurely die in several OECD countries. Among the OECD, Australia has conducted a commendable job in addressing the barriers on healthcare professionals. Although, the situation is still unfolding, few research articles and news clips are attempting to understand the gravity of the situation. Some have reflected on the emotional status of the healthcare professionals [28], while others have suggested on linguistic and communication barriers. For Australian context, Lakhani [29] conducted spatial analysis to understand the most vulnerable populations depending on their characteristics for Melbourne region.

Finally, the survivability of the patients is determined by utilizing either the overall survival or relative survival measures. Overall survival is defined as an estimate of survival from initiation of either the diagnosis or the medication. Whereas, relative survival is defined as an estimate of net survival which measures the deaths specifically associated with cancer diagnosis [22]. Such risks are also dependent on SES, therefore, relative excess risk (RER) has been defined which is the ratio of excess risk of death in a particular SES quintile compared to that of the reference (least disadvantaged) SES group, controlling the other factors.

4. Results

In terms of health diseases, numerous studies have been conducted for various types of diseases, of which the greatest number of studies have been performed for cancer (35%), followed by primary health care (14%), dental care (11), cardiovascular (10%). Figure 5 depicts the studies conducted for various diseases.

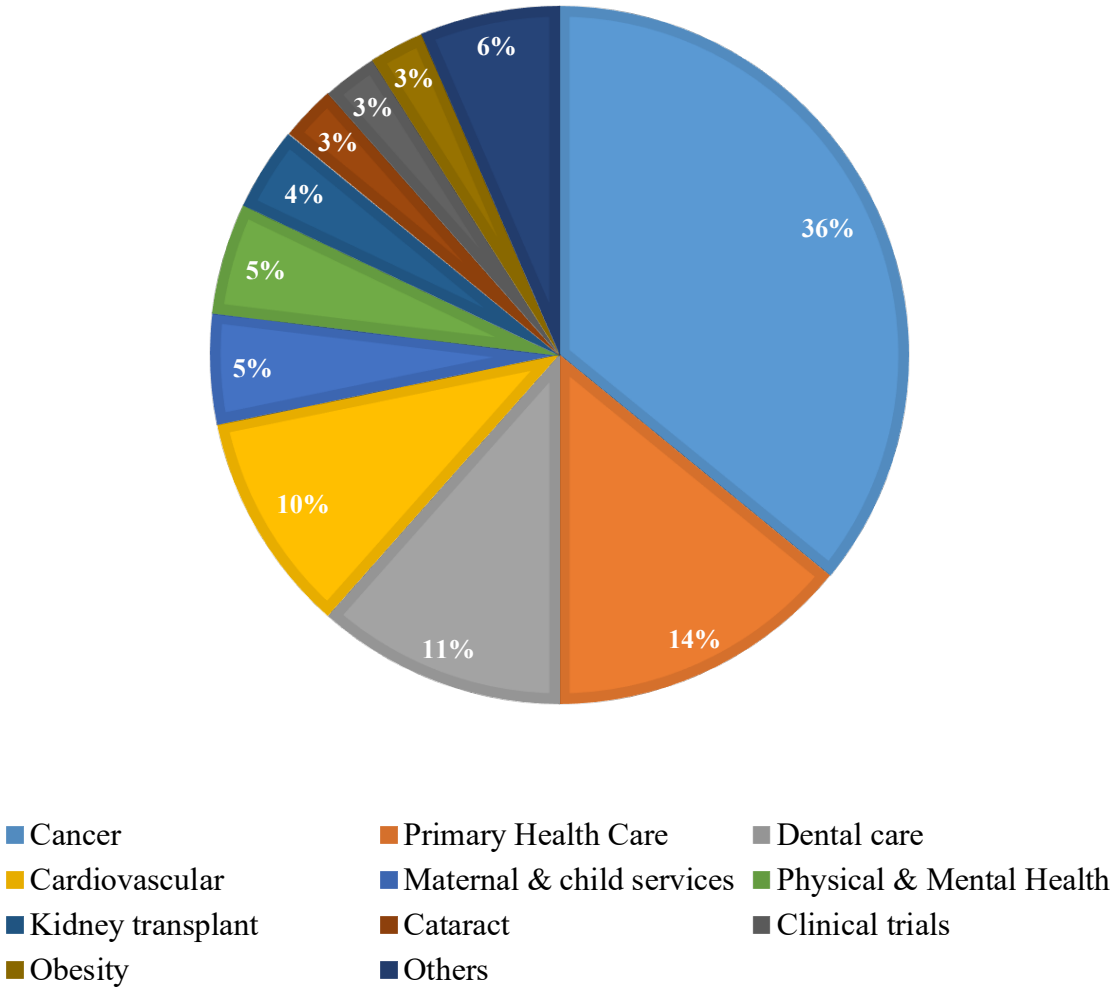

Figure 5. Percentage of studies conducted for various disease types (others include Diabetes, Disability, Frailty, Hepatitis C and Stroke, each contributing equally)

The studies have focused towards understanding the inequality to healthcare access based on various traits like location (rural, urban), origin (indigenous, non-indigenous), and access to health services. Among the various regions, most studies were performed for Queensland (38%), followed by New South Wales (34%), Victoria (14%) and the entire country (14%).

4.1 Cancer

Cancer is the most significant global public health problem and a leading cause of death and illness in the world in the 21st century, including Australia [30]. Breast cancer is estimated to be the most commonly diagnosed cancer in 2019, followed by prostate cancer. The distribution among the studies related to cancer types have also been varied with most studies being conducted on colorectal cancer followed by breast, prostate and lung cancer. Generally, the studies conducted form a framework in which the barriers are analysed independently as well as the interrelationship of barriers and determining its relationship with health outcome. The general accessibility factors like age, sex, patient characteristic, disease stage (incidence, various cancer stages) have been collected from the respective State's Cancer Registry. The distance to the health facility has been determined

by geocoding the location of all the facilities to the centroid of each SLA or to the address of the patient if available.

There seems to be a set framework when studying barriers to cancer care and considers various geographic and demographic parameters, thereby determining the survival rate. The remoteness index (ARIA+) and socio-economic index are considered when determining its effect on the patient survival.

The models used to determine the survivability include the Poisson regression model [31] and the Cox proportional hazards model [32]. The survivability can be expressed in either spatial [33] or temporal context [34]. Yu et al. [31] used Poisson regression model to determine the survivability by analyzing the residential location to diagnosis of colorectal cancer. However, Frowen et al. [35] investigated the impact of pre-treatment factors including demographic parameters. Baade et al. [36] determined the survival rate among colorectal cancer patients residing in Queensland. The study introduced a multilevel approach to assess the area-level variation in colorectal cancer survival due to causative factors (disease stage, co-morbidity, patient characteristics, and health care access) and analyze their individual contribution to survival. Baade et al. [32] analyzed the relation between distances to radiotherapy facilities and survival outcomes for rectal cancer patients in Queensland using the Cox proportional hazards regression. The results reveal that survival rate is low in areas of socio-economic disadvantage, remoteness and greater distance to radiotherapy facilities.

Hsieh et al. [37] quantified the additional barriers that impacted the treatment among women in Queensland diagnosed with breast cancer. Bayesian spatial modelling approach was used to analyze the spatial inequalities of utilizing the adjuvant therapy and found that socio-economic aspect does not play a significant role. However, the choice of therapy (radiotherapy, chemotherapy, hormonal therapy) is dependent on the age of the patient. Coory et al. [38] studied the disparity in cancer-related deaths among people residing in regional and remote areas for a period of 10 years (2001-2010). They used the arithmetic methodology, wherein the number of deaths precluded in Australia and excess cancer deaths in regional sections were computed. The results reveal that a slight improvement in curtailing the disadvantage of such areas with a death rate lower than metropolitan areas.

An interesting study was conducted by [39] wherein they introduced a new parameter "country of birth" along with socio-economic, remoteness and ethnicity among the patients diagnosed with cancer in New South Wales region. Logistic regression model was used to analyze the relation between variables and distant summary stage. The results reveal that people born outside of Australia were more likely to be diagnosed along with socio-economic status also playing a significant role.

Mahmud et al. [30] used multivariate analysis to analyze the trends associated with cancer incidence, hospitalisation, and fatality for several barriers. The study was conducted for the period 1982-2014 and the results revealed that socio-economic and geographical access plays a significant role in the patient outcome. Even though there has been an improvement over the time period, significant improvements need to be made to improve the life span of people residing in regional areas.

4.2 Primary Health Care

The access to primary health care (PHC) via general practitioners (GP) is critical as key to improve health outcomes with more than 80% of people visiting at least once every year [40,41]. The access to it has been quite varied among people residing in rural and urban areas and thereby focus has been more on understanding the access of PHC in rural areas. It has been proven and accepted that with an increase in distance to health centers the utilization of such centers become less [42,43]. The studies have primarily focused more towards the spatial context.

The use of the 2SFCA method to analyze barriers to primary health care services in Australia for both at small and large catchments has been avidly used. There have been several improvements in the use of the 2SFCA approach, which was studied by [44]. These improvements included the addition of distance-decay function and variable distance-decay function. The distance-decay

function included the aspect of consideration of distance/time when calculating barriers within a catchment. Whereas, the inclusion of variable distance-decay function considers the situations in which travel distance is more as per the health service required. Such a situation is quite evident in rural areas where a patient may need to travel further for a specific health service requirement as the services are sparsely distributed. This variation was explored by [45] for Victoria region wherein they limited the number of health services to 100 with a travel time of up to 60 minutes. McGrail et al. [40] developed a National Index of Access which contributed towards an improved understanding of spatial accessibility towards locating areas with access disadvantages and could be used for proper health planning. Similar study was conducted by [43,46] for 5 communities of Victoria and New South Wales region for metropolitan Adelaide region, respectively. The results revealed that travel behavior needs to be considered when analyzing accessibility. However, the variation was understood only by categorizing the population in rural and urban, which may not provide accurate results when analyzing large study area. This was overcome by the same authors [47], where they defined rules for selection of catchment with respect to travel time and the number of health services and performed the study for the entire country. The fundamental challenge of using the 2SFCA method is the definition of catchments, and researchers have been attempting to define new ways which has the ability to accurately assess the disparity for access to GPs in rural and urban regions [48].

However, these studies failed to consider the socio-economic status of the population studied. This aspect was explored by [49], which was performed for the inner regional area of New South Wales. The study applied the bivariate analysis to understand the relationship between remoteness and socio-economic status, leading to the construction of a composite score of deprivation. Thereafter, a pair-wise correlation matrix between the number of physicians, remoteness and socio-economic status was performed, and validating it with the health outcomes. The results reveal that socio-economic status plays a significant role compared to remoteness and physician for determining risk per 1000 persons. Schofield et al. [50] utilized 6 different variables (sex, age, income, remoteness, health status, employment status) to understand GP access, focusing on people with low socio-economic status and residing in rural areas. The results indicate that the services of GP do not depend on the per capita utilization of the services, irrespective of residing in rural and non-rural areas. However, this relation may not be accurate when considering Indigenous people. The inclusion of indigenous people towards understanding the barriers to access PHC services was studied by [41], which highlighted the need for considering indigenous staff also as social and cultural bias may exist. Gibson et al. [51] conducted an in-depth study by reviewing the articles related to the barriers faced by Indigenous people for assessing PHC.

It is evident that primary health care is probably the most basic and frequently visited health center by a population of various regions, ethnicity, and socio-economic status. Therefore, it is imperative to understand the various barriers faced by every section of society. The focus has primarily been on understanding the association between remoteness and health outcomes. Several other regions are yet to be been explored with the focus shifting towards local regions and considering the social and cultural aspects of the population which would provide an accurate understanding of the access barriers.

4.3 Dental Care

The studies involving dental care have been more focused towards the spatial understanding of the barriers [13-16,52]. Also, the focus seems to be on the analysis between public and private dental clinics, where roughly 80% of population visit private clinics [52]. Most of the studies used the line-of-sight to measure distances to dental care instead of determining travel time as they have focused in metropolitan regions with a focus on using geospatial tools to identify the accessibility [13,16]. The study by [52] focused on private dental clinics in Western Australia region and found that rural areas are more disadvantaged compared to the metropolitan areas. McGuire et al. [13] conducted the study for Victoria and found that almost three-quarters of population reside within 10km of a dental clinic. Almado et al. [16] analyzed the dental clinic accessibility for eight metropolitan cities of Australia.

The analysis revealed that only 33%-50% of the people were able to avail dental services depending on various capital city locations. However, an interesting study was conducted by [26] in which they analyzed the barriers faced by people with disabilities residing in Adelaide. The study was analyzed using bivariate and multivariate models and the results reveal that access is poor for people with disabilities living in rural compared to people in community settings. The study also found a significant barrier to access dental care is the unwillingness of dentists to treat disable people. Similar study was conducted by [27,53] for homeless people in Brisbane and identified fear as a barrier among the homeless population.

4.4 Physical and Mental Health

Mental health is essential and can be considered as the poorest service in terms of access, especially in rural and remote areas of the country [54]. Taylor et al. [55] studied the state among patients experiencing mental health issues who were needed to be transferred in metropolitan health centres. Qualitative analysis was performed through interviews conducted among six patients and 21 medical staff of Southern Australia region to understand the barriers faced while transferring patients. Fennell et al. [56] conducted a similar study for adults living in rural parts of South Australia and suggested that health professionals need to be educated about the barriers. Also, they attempted the evidence-based approaches to understand the concerns faced by patients. Saurman et al. [54] analyzed the Mental Health Emergency Care (MHEC) Rural Access Project implemented in New South Wales ensuring 24h access to specialists over video conferencing using concurrent mixed method approach. Wohler and Dantas [57], conducted a review on the barriers faced by immigrant and refugee women for accessing mental health services in Australia. The study highlighted that the barriers include factors like religion, self-reliance and resilience, suggesting measures need to be undertaken to address the concern. Maas et al. [58] conducted spatial analysis using autocorrelation indexes and spatial regression to determine patterns of referrals for a mental health programme for Western Sydney region. The results reveal that the distribution formed a pattern covering the areas with low socio-economic status.

The factors affecting easy access to mental healthcare programmes are varied and efforts need to be made to analyze the barriers at local scale and implement steps to overcome the barriers. However, the works clearly depict that indigenous people, area remoteness and low-income people are most affected.

4.5 Heart Related Studies

Cardiovascular disease (CVD) contributes to almost 35% of deaths in the country and is the second most affected disease after cancer [59]. This section discusses about the studies related to cardiovascular diseases and cardiac rehabilitation services. Studies have relied on GIS to determine the remoteness and accessibility. Bamford et al. [60] developed Cardiac ARIA to quantify the accessibility to the cardiac services by the available road networks. The significant difference between ARIA and Cardiac ARIA lies in the selection of a location for accessibility modelling. ARIA uses the population location whereas Cardiac ARIA uses the location of health service. Cardiac ARIA measures travel time to relevant health centers in two categories: a) Acute Cardiac ARIA which determines the travel time by ambulance in the event of an acute cardiac arrest b) Aftercare Cardia ARIA which evaluates the travel time by private transport after hospital discharge. Coffee et al. [59] calculated the Cardiac ARIA index for the entire country based on both the categories and concluded that the current system provides timely access to the majority of the population.

Cardiac rehabilitation serves as a primary step for preventing CVD and its access has been of major concern, especially in remote areas [61]. Higgins et al. [62] reported that the percentage of people attending rehabilitation programs after coronary artery bypass graft surgery varies from 37%-66% and identified the lack of effective referral protocols as a major factor. They based their study on the patients admitted at the Royal Melbourne Hospital, Victoria, and used the logistic regression model to determine patient characteristics related with visiting the rehabilitation programs. The uneven distribution of cardiovascular services in the country was highlighted by [63], which argued

that barriers are not only confined to the distance and transport reliability but is multidimensional involving other socio-economic parameters. Van Gaans et al. [64] developed the spatial model of accessibility involving both the geographic and the socio-economic factors. The model determined the ratings based on the patients who enrolled in the program versus completion rate of the program.

4.6 Other Diseases

The other diseases where the relation between the barriers and the health outcome has been studied include obesity, kidney transplant, diabetes, stroke, and services like clinical trials and maternity. The increase in the number of people being obese has increased drastically over the last three decades [65]. Remoteness and socio-economic disadvantage have been found to be the most critical factor affecting obesity [66,67]. The relationship between these factors to body mass index among Australian immigrants was studied using statistical analysis by [65].

In terms of wait listing for kidney transplantation, [21] studied the various barriers faced by the patients. The study was conducted using the univariate and multivariate models and found that access to the waitlist is based on numerous factors like sex, ethnicity and remoteness. The disparity faced by indigenous people over nonindigenous for kidney transplant accessibility was studied by [68]. Statistical analysis including the Cox proportional hazards model was used to understand the disparity.

Scott et al. [69] used regression models to analyze the demographic relationship with healthcare service coverage for Hepatitis C virus. The results reveal that despite the cost of the drug being low, more than 50% of the geographical area treated less than 10% of people suffering with the virus. Gilbert et al. [70] conducted a qualitative study to understand the barriers faced by patients when accessing the cataract surgery. They found five significant parameters, i.e., travel time, reputation of health center, surgeon experience, cost and the wait time for surgery. Sabesan et al. [71] analyzed the willingness for clinical trials among rural and regional patients of North Queensland. Using data of 178 patients and statistical analysis, found that the rural patients are more willing compared to the urban patients. Zdenkowski et al. [72] analyzed the barriers faced by patients when enrolling in a clinical trial for cancer medication. The study was performed by conducting interviews among 188 people under various scenarios ranging from variation in travel time, change in oncologist, trial type and increase in cost. Logistic regression was used, and the results reveal that if the cost and the oncologist remained same, the willingness of participants were more. However, increase in travel time led to a decrease in participation, whereas there was no difference with the trial type.

5. Discussions

The outcome of the review (Figure 6) could be useful for researchers to understand the various modelling approaches used for understanding barriers to healthcare access in Australia and could also be used in other countries with similar diversity. It provides a broad understanding of the techniques being used which could serve as a starting point for researchers looking to work in this domain for the first time. The analysis can be useful to identify some existing shortcomings and the important research questions to be addressed in the future.

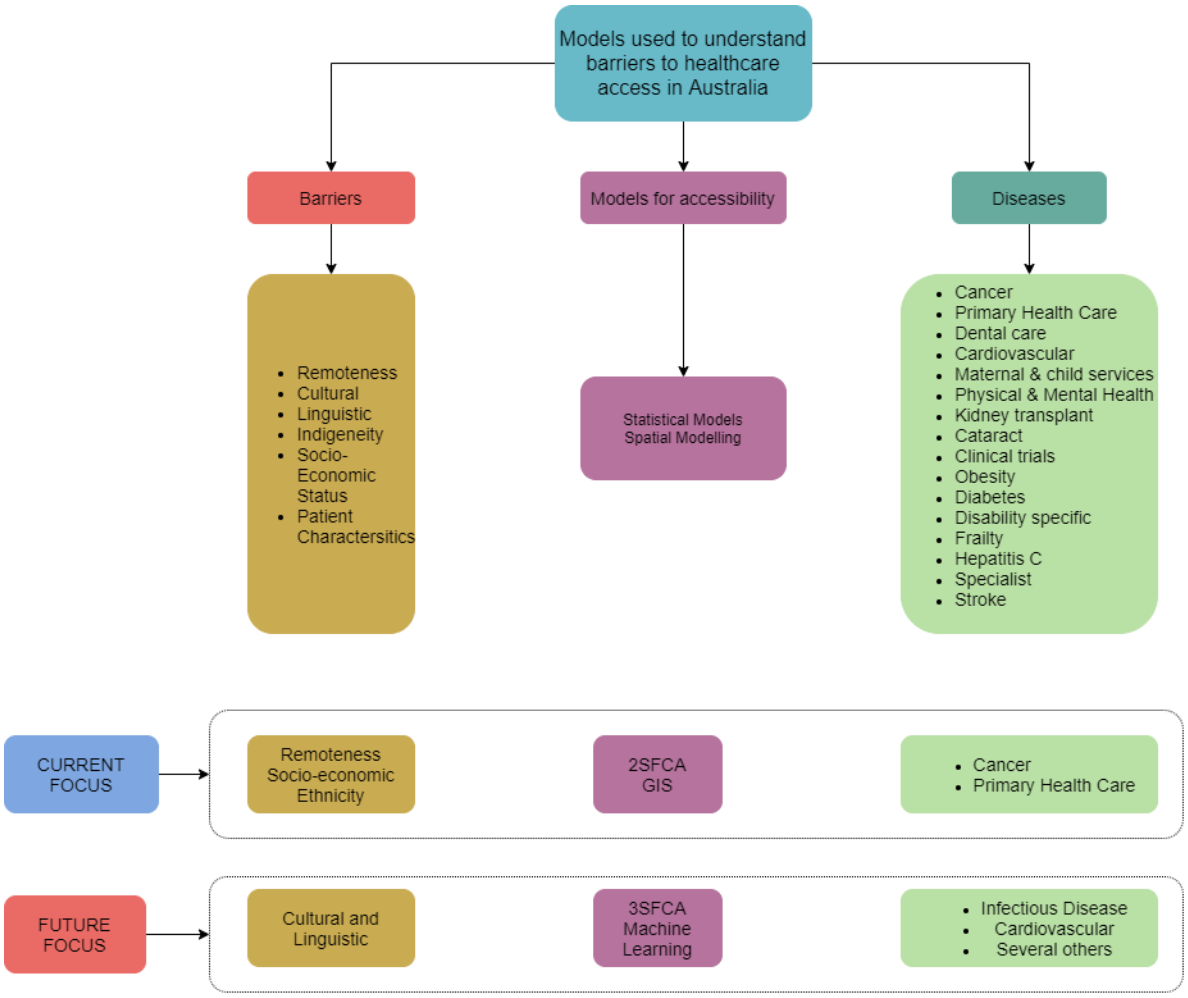

Figure 6. Flowchart of the study being conducted for the present study and the future directions.

The first gap is to focus towards other diseases apart from cancer. Primarily, more research has been conducted towards cancer, which is understandable due to the high number of patients suffering and leading to fatality. However, more efforts need to be put towards focusing on other major health issues. The second issue is the lack of studies on a finer scale as most of the studies conducted are either of an entire state or of the whole country. Certain barriers for a specific disease type are pertinent at a local level and their understanding on accessibility is also critical. Therefore, emphasis should be on focusing towards understanding barriers at a local scale. The COVID19 pandemic has shown the gaps present in the healthcare system in dealing with infectious diseases and our lack of research towards handling barriers for both patients and healthcare workers. Although the Australian health system has considerably performed well as compared to other economically developed countries, our understanding towards the barriers need to be comprehensively studied over future infectious disease outbreak. In general, the barriers are providing sufficient testing capacities, emotional and physical stress among the health workers and the dispersion of accurate information among the general public.

While understanding various healthcare barriers, accessibility, specifically spatial accessibility is one specific area where a lot of improvements can be made. The spatial mobility aspect can be considered as the most significant barrier to healthcare access. While the topic has been very well studies in fields of traffic monitoring and congestion, its application to healthcare studies in Australia has been limited. In terms of spatial accessibility to health facilities, it can be broadly categorized into two sections: i) navigation to a health centers which could be proximity to health center as well as distance or travel time between a certain location and health center, which would be critical in case of medical emergencies, ii) Setup of new health facilities which can be achieved by considering the

population demand according to the diseases suffering along with considering other factors like affordability, indigenous status. For both these aspects, use of GIS integrating with the transport model and concept of spatio-temporal paths should be encouraged [73]. The spatial accessibility understanding during the pandemic outbreak has revealed some serious gaping holes in the system and the decision makers.

5.1 Navigation to Health Centres

While the studies in Australian context have focused more towards the use of the 2SFCA and other statistical models to calculate distance to health centers, focus should shift towards considering different techniques, e.g. the Three Step Floating Catchment Area (3SFCA) which uses distance, proximities and population demand. It could also help in identifying the disparity of health care access at a regional level study. Apparicio et al. [74] analyzed the accessibility to health services using various distance and aggregation methods. Such analysis needs to be performed at various spatial scales (national, regional and local) to standardize the basic methodology to be used, which can then be improved in the future. Also, the input data used for conducting similar studies relies heavily on Google Earth/Maps or Open Street Map. Efforts need to be made on using high spatial dataset [75] which would improve the spatial mobility significant in health scenarios. Such use of high spatio-temporal dataset would help in identifying the nearest health center along with the shortest route to reach considering the population density [76]. This would immensely support the decision makers and stakeholders to gain better access to health centers. The recent work by [77] on determining distance and travel time for Helsinki, Finland using several transportation modes provides a path on deciding the travel mode to be used, in cases of medical emergency, clinical check-up and rehabilitation. Such development of disease specific travel time dataset like check-up of breast and prostate cancer, dental care and GPs could serve better for the people to decide which health facility to go to.

5.2 Location of new health facilities

It has been well acknowledged that the remote areas suffer from an adequate number of health centers, also the type of health centers for a specific disease type is quite erratic even in urban areas. Although the specialized field of analyzing setup of new health centers is a separate entity, we attempt to look it solely from the different barrier point of view. The lack of facilities can be overcome with setting up of new facilities, but the challenges could be ranging from accessibility, cultural and affordability. The accessibility component can be solved by utilizing the measures mentioned above, however the other challenges would be detrimental which could be understood by conducting interviews and understanding the specific requirements at a community level. The challenge lies in setting up new health centers specific to community-based barriers with the consideration of socio-economic status as well as cultural and regional biasness. The steps to set up a new health center could initiate with understanding of broader aspects like accessibility and affordability, and thereafter filling the gaps of cultural differences with a capacity to upgrade in the future. Another important aspect found while conducting review was the comparison between rural and urban healthcare accessibility with few studies comparing various metropolitan regions. However, the studies on comparison between accessibility and health outcomes among the rural regions in a state or across several states was not heavily researched. Such analysis would be interesting to understand which states outperform the rural health care services and thereafter necessary steps can be taken by the respective state health departments to improve the services. Care must be taken while analyzing the rural regions as patient characteristics like indigeneity, cultural and linguistic barriers would be critical while addressing rural health issues.

6. Conclusions

The review paper is an attempt to analyze the models used to understand barriers to healthcare access and the survivability of the patient across various disease types. The current research practice

is lacking, ranging from spatial accessibility techniques, consideration of patient characteristics aspects, analyzing various disease types as well as studies concerning only to rural/remote areas. Also, our understanding on barriers towards infectious disease outbreak is still in infancy and the COVID 19 situation would help in determining the various concerns among the patients and health workers, which should be implemented in the future. The study highlighted key areas in which the research has focused: cancer and primary health care related studies, 2SFCA method and rural vs urban health outcomes. The conclusions from the study are as follows:

1) Of the several barriers, it's important to note that the barriers are multifaceted, of which the major barriers are geographic, ethnicity and socio-economic status. The most deprived section for healthcare access is the indigenous people, which could be even worse if their economic status is poor. The focus needs to shift towards addressing the cultural and linguistic barrier, especially of the indigenous people. There are several other barriers also which are characteristic to the disease the patient is suffering from.

2) As most studies have focused on a large geographical area, the distance/time determination using smallest administrative boundary for better accuracy, have been missed. Emphasis should be on analyzing at the smallest administrative boundary. Also, the focus has primarily been on few diseases only, like cancer, primary health care, wherein the location of the study has focused primarily in few states only. Both the aspects need to be improved, type of disease and the study area.

3) The distance/time calculation to health centers are determined spatially using GIS using various geospatial tools. It's encouraging that the available models have been tested very extensively for different regions and have proved to be performing well, like the 2SFCA method. However, new models and techniques like 3SFCA and machine learning needs to be attempted for better accuracy. The increase in the availability of data would help in developing machine learning based tools aimed in identifying key shortcomings, and the steps needed to be taken for better health care access at both local and regional scale.

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References

1. Barbieri, S.; Jorm, L. Travel times to hospitals in Australia. *Scientific Data* **2019**, *6*, 248, doi:10.1038/s41597-019-0266-4.
2. Haynes, R. Geographical access to health care. *Access to health care* **2003**, 13-35.
3. Kelly, C.; Hulme, C.; Farragher, T.; Clarke, G. Are differences in travel time or distance to healthcare for adults in global north countries associated with an impact on health outcomes? A systematic review. *BMJ open* **2016**, *6*, e013059.
4. Weinhold, I.; Gurtner, S. Understanding shortages of sufficient health care in rural areas. *Health Policy* **2014**, *118*, 201-214.
5. Rolfe, M.I.; Donoghue, D.A.; Longman, J.M.; Pilcher, J.; Kildea, S.; Kruske, S.; Kornelsen, J.; Grzybowski, S.; Barclay, L.; Morgan, G.G. The distribution of maternity services across rural and remote Australia: does it reflect population need? *BMC health services research* **2017**, *17*, 163.
6. Li, J.-L. Cultural barriers lead to inequitable healthcare access for aboriginal Australians and Torres Strait Islanders. *Chinese Nursing Research* **2017**, *4*, 207-210.

7. McBain-Rigg, K.E.; Veitch, C. Cultural barriers to health care for Aboriginal and Torres Strait Islanders in Mount Isa. *Australian Journal of Rural Health* **2011**, *19*, 70-74.
8. Penchansky, R.; Thomas, J.W. The concept of access: definition and relationship to consumer satisfaction. *Medical care* **1981**, 127-140.
9. Guagliardo, M.F. Spatial accessibility of primary care: concepts, methods and challenges. *International journal of health geographics* **2004**, *3*, 3.
10. Wang, F.; Luo, W. Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. *Health & place* **2005**, *11*, 131-146.
11. McGrail, M.R.; Humphreys, J.S. Measuring spatial accessibility to primary care in rural areas: improving the effectiveness of the two-step floating catchment area method. *Applied Geography* **2009**, *29*, 533-541.
12. Song, Y.; Tan, Y.; Song, Y.; Wu, P.; Cheng, J.C.; Kim, M.J.; Wang, X. Spatial and temporal variations of spatial population accessibility to public hospitals: A case study of rural–urban comparison. *GIScience & remote sensing* **2018**, *55*, 718-744.
13. McGuire, S.; Kruger, E.; Tennant, M. Travel patterns for government emergency dental care in Australia: a new approach using GIS tools. *Australian Dental Journal* **2011**, *56*, 389-393.
14. Rocha, C.; Kruger, E.; McGuire, S.; Tennant, M. The geographic distribution of patient seeking emergency dental care at the Royal Dental Hospital of Melbourne, Australia. *Community dental health* **2013**, *30*, 149-154.
15. Rocha, C.; Kruger, E.; McGuire, S.; Tennant, M. Weekend emergency dental care demand: a study of the geographic and socioeconomic catchment for a major metropolitan dental hospital in Australia. *Asia Pacific Journal of Health Management* **2013**, *8*, 24.
16. Almado, H.; Kruger, E.; Tennant, M. Application of spatial analysis technology to the planning of access to oral health care for at-risk populations in Australian capital cities. *Australian journal of primary health* **2015**, *21*, 221-226.
17. Luo, W.; Wang, F. Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region. *Environment and Planning B: Planning and Design* **2003**, *30*, 865-884.
18. Radke, J.; Mu, L. Spatial decompositions, modeling and mapping service regions to predict access to social programs. *Geographic Information Sciences* **2000**, *6*, 105-112.
19. Dixit, S.K.; Sambasivan, M. A review of the Australian healthcare system: A policy perspective. *SAGE open medicine* **2018**, *6*, 2050312118769211.
20. Calder, R.; Dunkin, R.; Rochford, C.; Nichols, T. Australian health services: too complex to navigate: a review of the national reviews of Australia's health service arrangements. **2019**.
21. Sypek, M.P.; Clayton, P.A.; Lim, W.; Hughes, P.; Kanellis, J.; Wright, J.; Chapman, J.; McDonald, S.P. Access to waitlisting for deceased donor kidney transplantation in Australia. *Nephrology* **2019**, *24*, 758-766.
22. Duncan, E.W.; Cramb, S.M.; Aitken, J.F.; Mengersen, K.L.; Baade, P.D. Development of the Australian Cancer Atlas: spatial modelling, visualisation, and reporting of estimates. *International journal of health geographics* **2019**, *18*, 21.
23. Bray, J.E.; Coughlan, K.; Mosley, I.; Barger, B.; Bladin, C. Are suspected stroke patients identified by paramedics transported to appropriate stroke centres in V ictoria, A ustralia? *Internal medicine journal* **2014**, *44*, 515-518.

24. Satasivam, P.; O'Neill, S.; Sivarajah, G.; Sliwinski, A.; Kaiser, C.; Niall, O.; Goad, J.; Brennan, J. The dilemma of distance: patients with kidney cancer from regional Australia present at a more advanced stage. *BJU international* **2014**, *113*, 57-63.
25. Stanbury, J.F.; Baade, P.D.; Yu, Y.; Yu, X.Q. Impact of geographic area level on measuring socioeconomic disparities in cancer survival in New South Wales, Australia: a period analysis. *Cancer epidemiology* **2016**, *43*, 56-62.
26. Pradhan, A.; Slade, G.; Spencer, A. Access to dental care among adults with physical and intellectual disabilities: residence factors. *Australian dental journal* **2009**, *54*, 204-211.
27. Stormon, N.; Pradhan, A.; McAuliffe, A.; Ford, P. Does a facilitated pathway improve access to dental services for homeless and disadvantaged adults? *Evaluation and program planning* **2018**, *71*, 46-50.
28. Selikowitz, A. Mental health challenges for healthcare workers during the COVID-19 pandemic – Impact and management strategies. Availabe online: (accessed on 24/05/2020).
29. Lakhani, A. Which Melbourne Metropolitan Areas Are Vulnerable to COVID-19 Based on Age, Disability, and Access to Health Services? Using Spatial Analysis to Identify Service Gaps and Inform Delivery. *Journal of Pain and Symptom Management* **2020**, https://doi.org/10.1016/j.jpainsymman.2020.03.041, doi:https://doi.org/10.1016/j.jpainsymman.2020.03.041.
30. Mahumud, R.A.; Alam, K.; Dunn, J.; Gow, J. Emerging cancer incidence, mortality, hospitalisation and associated burden among Australian cancer patients, 1982–2014: an incidence-based approach in terms of trends, determinants and inequality. *BMJ open* **2019**, *9*.
31. Xue, Q.Y.; O'Connell, D.L.; Gibberd, R.W.; Armstrong, B.K. A population-based study from New South Wales, Australia 1996–2001: area variation in survival from colorectal cancer. *European Journal of Cancer* **2005**, *41*, 2715-2721.
32. Baade, P.D.; Dasgupta, P.; Aitken, J.F.; Turrell, G. Distance to the closest radiotherapy facility and survival after a diagnosis of rectal cancer in Queensland. *Medical Journal of Australia* **2011**, *195*, 350-354.
33. Cramb, S.M.; Mengersen, K.L.; Turrell, G.; Baade, P.D. Spatial inequalities in colorectal and breast cancer survival: premature deaths and associated factors. *Health & place* **2012**, *18*, 1412-1421.
34. Cramb, S.M.; Mengersen, K.L.; Baade, P.D. Spatio-temporal relative survival of breast and colorectal cancer in Queensland, Australia 2001–2011. *Spatial and spatio-temporal epidemiology* **2016**, *19*, 103-114.
35. Frowen, J.; Cotton, S.; Corry, J.; Perry, A. Impact of demographics, tumor characteristics, and treatment factors on swallowing after (chemo) radiotherapy for head and neck cancer. *Head & Neck: Journal for the Sciences and Specialties of the Head and Neck* **2010**, *32*, 513-528.
36. Baade, P.D.; Turrell, G.; Aitken, J.F. A multilevel study of the determinants of area-level inequalities in colorectal cancer survival. *BMC cancer* **2010**, *10*, 24.
37. Hsieh, J.C.-F.; Cramb, S.M.; McGree, J.M.; Dunn, N.A.; Baade, P.D.; Mengersen, K.L. Geographic variation in the intended choice of adjuvant treatments for women diagnosed with screen-detected breast cancer in Queensland. *BMC public health* **2015**, *15*, 1204.
38. Coory, M.D.; Ho, T.; Jordan, S.J. Australia is continuing to make progress against cancer, but the regional and remote disadvantage remains. *Medical Journal of Australia* **2013**, *199*, 605-608.
39. Tervonen, H.E.; Walton, R.; Roder, D.; You, H.; Morrell, S.; Baker, D.; Aranda, S. Socio-demographic disadvantage and distant summary stage of cancer at diagnosis—a population-based study in New South Wales. *Cancer epidemiology* **2016**, *40*, 87-94.

40. McGrail, M.R.; Humphreys, J.S. The index of rural access: an innovative integrated approach for measuring primary care access. *BMC Health Services Research* **2009**, *9*, 124.
41. Davy, C.; Harfield, S.; McArthur, A.; Munn, Z.; Brown, A. Access to primary health care services for Indigenous peoples: a framework synthesis. *International journal for equity in health* **2016**, *15*, 163.
42. Sibley, L.M.; Weiner, J.P. An evaluation of access to health care services along the rural-urban continuum in Canada. *BMC health services research* **2011**, *11*, 20.
43. McGrail, M.R.; Humphreys, J.S.; Ward, B. Accessing doctors at times of need–measuring the distance tolerance of rural residents for health-related travel. *BMC health services research* **2015**, *15*, 212.
44. McGrail, M.R. Spatial accessibility of primary health care utilising the two step floating catchment area method: an assessment of recent improvements. *International journal of health geographics* **2012**, *11*, 50.
45. McGrail, M.R.; Humphreys, J.S. A new index of access to primary care services in rural areas. *Australian and New Zealand journal of public health* **2009**, *33*, 418-423.
46. Roeger, L.S.; Reed, R.L.; Smith, B.P. Equity of access in the spatial distribution of GPs within an Australian metropolitan city. *Australian Journal of Primary Health* **2010**, *16*, 284-290.
47. McGrail, M.R.; Humphreys, J.S. Measuring spatial accessibility to primary health care services: Utilising dynamic catchment sizes. *Applied Geography* **2014**, *54*, 182-188.
48. McGrail, M.R.; Russell, D.J.; Humphreys, J.S. Index of access: a new innovative and dynamic tool for rural health service and workforce planning. *Australian Health Review* **2017**, *41*, 492-498.
49. Butler, D.C.; Petterson, S.; Bazemore, A.; Douglas, K.A. Use of measures of socioeconomic deprivation in planning primary health care workforce and defining health care need in Australia. *Australian Journal of Rural Health* **2010**, *18*, 199-204.
50. Schofield, D.J.; Shrestha, R.N.; Callander, E.J. Access to general practitioner services amongst underserved Australians: a microsimulation study. *Human resources for health* **2012**, *10*, 1.
51. Gibson, O.; Lisy, K.; Davy, C.; Aromataris, E.; Kite, E.; Lockwood, C.; Riitano, D.; McBride, K.; Brown, A. Enablers and barriers to the implementation of primary health care interventions for Indigenous people with chronic diseases: a systematic review. *Implementation Science* **2015**, *10*, 71.
52. Kruger, E.; Tennant, M.; George, R. Application of geographic information systems to the analysis of private dental practices distribution in Western Australia. **2011**.
53. Ford, P.; Cramb, S.; Farah, C. Oral health impacts and quality of life in an urban homeless population. *Australian dental journal* **2014**, *59*, 234-239.
54. Saurman, E.; Perkins, D.; Roberts, R.; Roberts, A.; Patfield, M.; Lyle, D. Responding to mental health emergencies: implementation of an innovative telehealth service in rural and remote New South Wales, Australia. *Journal of emergency nursing* **2011**, *37*, 453-459.
55. Taylor, J.; Edwards, J.; Kelly, F.; Fielke, K. Improving transfer of mental health care for rural and remote consumers in South Australia. *Health & Social Care in the Community* **2009**, *17*, 216-224.
56. Fennell, K.M.; Hull, M.; Jones, M.; Dollman, J. A comparison of barriers to accessing services for mental and physical health conditions in a sample of rural Australian adults. **2018**.
57. Wohler, Y.; Dantas, J.A. Barriers accessing mental health services among culturally and linguistically diverse (CALD) immigrant women in Australia: policy implications. *Journal of immigrant and minority health* **2017**, *19*, 697-701.
58. Maas, C.; Salinas-Perez, J.A.; Bagheri, N.; Rosenberg, S.; Campos, W.; Gillespie, J.A.; Salvador-Carulla, L. A spatial analysis of referrals to a primary mental health programme in Western Sydney from 2012 to 2015. *Geospatial health* **2019**, *14*.

59. Coffee, N.; Turner, D.; Clark, R.A.; Eckert, K.; Coombe, D.; Hugo, G.; van Gaans, D.; Wilkinson, D.; Stewart, S.; Tonkin, A.A. Measuring national accessibility to cardiac services using geographic information systems. *Applied Geography* **2012**, *34*, 445-455.
60. Bamford, E.J.; Taylor, D.S.; Hugo, G.J.; Dunne, L.; Symon, B.G.; Wilkinson, D. Accessibility to general practitioners in rural South Australia: a case study using geographic information system technology. *Medical Journal of Australia* **1999**, *171*, 614-616.
61. Bunker, S.J.; Goble, A.J. Cardiac rehabilitation: under-referral and underutilisation. *The Medical Journal of Australia* **2003**, *179*, 332-333.
62. Higgins, R.O.; Murphy, B.M.; Goble, A.J.; Le Grande, M.R.; Elliott, P.C.; Worcester, M.U. Cardiac rehabilitation program attendance after coronary artery bypass surgery: overcoming the barriers. *Medical Journal of Australia* **2008**, *188*, 712-714.
63. Clark, R.A.; Driscoll, A.; Nottage, J.; McLennan, S.; Coombe, D.M.; Bamford, E.J.; Wilkinson, D.; Stewart, S. Inequitable provision of optimal services for patients with chronic heart failure: a national geo-mapping study. *Medical journal of Australia* **2007**, *186*, 169-173.
64. van Gaans, D.; Hugo, G.; Tonkin, A. The development of a spatial model of accessibility to phase 2 cardiac rehabilitation programs. *Journal of Spatial Science* **2016**, *61*, 217-231.
65. Menigoz, K.; Nathan, A.; Heesch, K.C.; Turrell, G. Neighbourhood disadvantage, geographic remoteness and body mass index among immigrants to Australia: A national cohort study 2006-2014. *PloS one* **2018**, *13*.
66. King, T.; Kavanagh, A.M.; Jolley, D.; Turrell, G.; Crawford, D. Weight and place: a multilevel cross-sectional survey of area-level social disadvantage and overweight/obesity in Australia. *International journal of obesity* **2006**, *30*, 281-287.
67. Feng, X.; Wilson, A. Do neighbourhood socioeconomic circumstances not matter for weight status among Australian men? Multilevel evidence from a household survey of 14 691 adults. *BMJ open* **2015**, *5*, e007052.
68. Khanal, N.; Lawton, P.D.; Cass, A.; McDonald, S.P. Disparity of access to kidney transplantation by Indigenous and non-Indigenous Australians. *Medical Journal of Australia* **2018**, *209*, 261-266.
69. Scott, N.; Hainsworth, S.W.; Sacks-Davis, R.; Pedrana, A.; Doyle, J.; Wade, A.; Hellard, M. Heterogeneity in hepatitis C treatment prescribing and uptake in Australia: a geospatial analysis of a year of unrestricted treatment access. *Journal of virus eradication* **2018**, *4*, 108.
70. Gilbert, C.; Keay, L.; Palagyi, A.; Do, V.Q.; McCluskey, P.; White, A.; Carnt, N.; Stapleton, F.; Laba, T.L. Investigation of attributes which guide choice in cataract surgery services in urban Sydney, Australia. *Clinical and Experimental Optometry* **2018**, *101*, 363-371.
71. Sabesan, S.; Burgher, B.; Buettner, P.; Piliouras, P.; Otty, Z.; Varma, S.; Thaker, D. Attitudes, knowledge and barriers to participation in cancer clinical trials among rural and remote patients. *Asia-Pacific Journal of Clinical Oncology* **2011**, *7*, 27-33.
72. Zdenkowski, N.; Lynam, J.; Sproule, V.; Wall, L.; Searston, J.; Brown, S. Results of a survey of cancer patients' willingness to travel to participate in a clinical trial. *Internal medicine journal* **2019**, *49*, 1321-1325.
73. Loidl, M.; Wallentin, G.; Cyganski, R.; Graser, A.; Scholz, J.; Haslauer, E. GIS and transport modeling—Strengthening the spatial perspective. *ISPRS International Journal of Geo-Information* **2016**, *5*, 84.

713 74. Apparicio, P.; Gelb, J.; Dubé, A.-S.; Kingham, S.; Gauvin, L.; Robitaille, É. The approaches to measuring
714 the potential spatial access to urban health services revisited: distance types and aggregation-error
715 issues. *International journal of health geographics* **2017**, *16*, 32.
716 75. Weiss, D.J.; Nelson, A.; Gibson, H.; Temperley, W.; Peedell, S.; Lieber, A.; Hancher, M.; Poyart, E.;
717 Belchior, S.; Fullman, N. A global map of travel time to cities to assess inequalities in accessibility in
718 2015. *Nature* **2018**, *553*, 333-336.
719 76. Ramzi, A.I.; El-Bedawi, M.A.-L. Towards integration of remote sensing and GIS to manage primary
720 health care centers. *Applied Computing and Informatics* **2019**, *15*, 109-113.
721 77. Tenkanen, H.; Toivonen, T. Longitudinal spatial dataset on travel times and distances by different
722 travel modes in Helsinki Region. *Scientific data* **2020**, *7*, 1-15.
723

724