Access to dialysis services: A systematic mapping review based on geographical information systems

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Contributions: NB designed the study; BH searched for the literature. Then, the EndNote X5 (Thomson Reuters, New York, NY, USA) reference management software was applied to aggregate all the search strategy returns. Two reviewers (BH and BK) screened the exported articles in EndNote and compared them with the inclusion and exclusion criteria independently. Any disagreement was resolved by another reviewer (MT), who was also responsible for the supervision of the research. Each study was assessed independently by two reviewers for the eligibility criteria. The full text of the qualified studies was retrieved and saved. The eligible papers were read, tagged and summarized by one reviewer (BH) and then verified by the second reviewer (MT). Quality scores were assigned by two reviewers (BH and AA) and verified by the third reviewer (HT). BH wrote the draft of the paper. BK and BH reviewed the paper and made revisions.

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Abstract

Equitable access to healthcare services constitutes one of the leading priorities of healthcare provision and access to dialysis services (ADS) has an essential impact on patients depending on renal dialysis. The many existing GIS-based ADS evaluations include various spatial and non-spatial factors affecting ADS. We systematically mapped and reviewed the available literature with reference to this area identifying gaps in current GIS-based ADS measures and developing recommendations for future studies. A threestep, systematic mapping review of the available GIS-related evidence in PubMed, Embase, Web of science, Scopus, Science Direct and IEEE Xplore was performed in May 2016 and the information collected updated October 2017 by two independent selection processes. The quality of the studies was assessed using an informal, mixed-approach scoring system. Out of 1119 literature references identified, 36 were identified and used for final review after removal of duplicates, study screenings and applying inclusion/exclusion criteria. Given the contents of the selected studies, three study groups were identified and 41 factors with potential effects on ADS determined. These studies mainly addressed the potential and/or spatial aspects of ADS. Our systematic mapping review of the evidence revealed that current GIS-based measures of ADS tend to calculate potential ADS instead of a realized one. It was also noted that listed factors affecting ADS were mainly non-spatial bringing forth the hypothesis that designing an integrated ADS index could possibly produce better ADS score than those currently advocated. Some primary and secondary research suggestions are made and a list of recommendations offered.

Introduction

Although equitable access to healthcare services (AHS) is a leading public health priority, the importance of AHS and the attention received from the policy managers differ from one disease to another. Access to dialysis services (ADS) is a crucial necessity for patients who have to travel to a dialysis facility three times a week (Mactier, 2007; Stephens et al., 2013). Thus, poorly developed ADS lead to poor health outcomes such as increased morbidity and mortality (Moist et al., 2008; Diamant et al., 2010; Rucker et al., 2011; Thompson et al., 2012).

A vital aspect of AHS is the ease with which they can be
Review

Materials and Methods

A systematic mapping review of the available GIS-based literature was performed. It aimed to describe the extent of the study on a particular topic and to identify knowledge gaps in the study base, where further primary and/or secondary studies are needed (Grant and Booth, 2009).

Search strategy

The scientific literature was explored with regard to relevant communications on ADS and the use of GIS. It was done in May 2016 and the information collected updated in October 2017. We included the following electronic databases: PubMed, Web of Science, Scopus, ScienceDirect, EMBASE and IEEE Xplore. Initially, the databases were systematically searched using a variation of access concept (access, accessibility, availability, affordability, acceptability, accommodation, utilization, deprivation, disparity and equity) in connection with spatial terms (geographic information, GIS, geomapping, location-allocation, and spatial analysis) and dialysis (dialysis, haemodialysis, renal and kidney). To combine the search terms within each category, we utilized the disjunction OR, and to combine categories we utilized the conjunction AND.

In order to identify additional relevant information related to ADS and GIS, the reference lists obtained were surveyed manually. To boost our search strategy further, we also looked for the so called gray literature, i.e. reports, standards, manuals and guidelines on the topic using general search engines such as Google. No date or study design limitation was imposed in any of the research steps described. The complete search strategy is available upon request.

Eligibility criteria

After the literature search had been completed, the EndNote X5 (Thomson Reuters, New York, NY, USA) reference management software was applied to aggregate all search returns. The articles were then screened and each study assessed independently for eligibility by two of the authors in different combinations. A study was considered eligible for inclusion if it included assessment of ADS as the primary or secondary outcome, while it was excluded if i) it had not clearly reported and calculated ADS indicators; ii) it lacked a methodological description of the measurement of ADS or its indicators; or iii) it consisted of a letter to the editor, an editorial, general comments, a position paper or it was an unstructured paper.

The full text of the qualified studies was read, tagged and summarized by one author and verified by one other author. A brief flow diagram of the strategy is depicted in Figure 1.

Data extraction

Studies deemed eligible for review underwent data extraction. For each paper, essential data items related to ADS measurement were extracted and fitted into a form with a choice of headings, such as ADS indicator; Factor(s) affecting the indicator; Method of measurement; Primary outcome measures; Secondary outcome measures; and Study design. Additional properties, such as conclusive comments and suggested measurement intervals, were also recorded when available and applicable.
Quality assessment

Since systematic mapping reviews mainly aim to describe the state of the art of a particular topic, it is desirable to include communication types of a range as wide as possible. Due to the high diversity of study types in our review, this necessitated an informal quality assessment that was performed by classifying the literature by type of study. We used a mixed-approach scoring system as applied by Azizi et al. (2016) under similar circumstances (Azizi et al., 2016). Quality scores were assigned by two authors and verified by a third author. The weight of the literature was assigned according to their study design by the quality scoring system. In this approach, papers such as reviews and randomized controlled trials (RCTs) achieved the highest score (score 4) while score one was the lowest score. In this approach, the gray literature was given score one as formal or expert consensus regarding quality score. The summary of the quality assessment approach is outlined in Table 1.

Data analysis

Following mapping review methods, a tabular method for the synthesis of qualitative research findings was used. Also, the quantity and quality of the literature were characterized by study design and other key features, and need for some primary or secondary research was identified.

Results

Out of 1119 literature items collected, 76 were deemed eligible for further full-text review. After reviewing the full-text studies for final content match, 36 were selected for the review. Further details pertaining to the included studies are shown in Figure 1.

Characteristics of included studies

Three groups of studies were identified. The first group included eight cross-sectional studies addressing ADS and treating it as a primary outcome. The focus of these communications was the design of a GIS-based model intended for gauging the degree of ADS. They mostly calculated potential travel time (Roderick et al., 1999; Christie et al., 2005; White et al., 2006; Yang et al., 2006; Judge et al., 2012; Matsumoto et al., 2012; Stephens et al., 2013) or facility capacity (White et al., 2006; Yang et al., 2006; Matsumoto et al., 2012) as the key indicators of spatial accessibility. Some papers in this group also considered deprivation (Roderick et al., 1999; Christie et al., 2005; White et al., 2006; Judge et al., 2012) as an important, non-spatial indicator of ADS. One study designed a measure to calculate actual travel time revealed significant effects on the travel time of other non-spatial factors such as sex, income level, caregivers, transportation mode, education level, ethnicity and personal vehicle ownership. It demonstrated the large gap between potential travel time and actual travel time (Kiani et al., 2017). Another study showed that ignoring facility capacity and accounting only for travel time when evaluating ADS may result in misleading conclusions (Matsumoto et al., 2012). Further details pertaining to this group are outlined in Table 2.

The second group of studies (10 peer-reviewed papers) considered gauging ADS as a secondary outcome, while their primary outcome measures focused on the association between ADS and health-related outcomes (Tonelli et al., 2007; Moist et al., 2008; Diamant et al., 2010; Rucker et al., 2011; Thompson et al., 2012; Miller et al., 2014) determining the relationship between ADS and prevalence rates of dialysis patients (Kashima et al., 2012) or designing models to locate dialysis facilities (Ayyalasomayajula et al., 2011; Salgado et al., 2011; Faruque et al., 2012). Almost all of them calculated potential travel impedance as an indicator of ADS based on GIS.

Finally, the third group of 16 studies considered factors affecting ADS. Among them, were ten peer-reviewed articles (Smith et al., 1985; Tonelli et al., 2006; Hall et al., 2008; Prakash et al., 2010; Matsumoto et al., 2013; Omrani-Khoe et al., 2013; Rodriguez et al., 2013; Plantinga et al., 2014; Saunders et al., 2014; Kiani et al., 2017), one case series (Tshamba et al., 2014), one proceeding (Richard et al., 2009), and four gray literature items (Maheswaran et al., 2003; Mactier, 2007; Levinson, 2011; Amy Martin, 2013).

Considering the contents of the total number of GIS-based studies discussed here and the literature extracted from their comprehensive reference lists, 41 factors affecting ADS were determined (Table 3). Travel impedance, especially travel time, were the main indicators of spatial accessibility, the rest were mostly non-spatial. Some studies emphasize that factors such as ethnicity or the patient’s health insurance status also affect ADS (Kashima et al., 2012; Thompson et al., 2012; Saunders et al., 2014), while other studies imply that they do not affect ADS (White et al., 2006; Matsumoto et al., 2012). The factors we found in our literature search and their frequency are given in Table 3.

Table 1. Classification according to evidence quality.

<table>
<thead>
<tr>
<th>Type of evidence</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCT*, meta-analysis, systematic review</td>
<td>4</td>
</tr>
<tr>
<td>Case-control, cohort studies, quasi-experimental studies</td>
<td>3</td>
</tr>
<tr>
<td>Observational studies (case reports, case series)</td>
<td>2</td>
</tr>
<tr>
<td>Formal/expert consensus</td>
<td>1</td>
</tr>
</tbody>
</table>

*Ranomized controlled trial.
Discussion

Our systematic mapping review of the evidence revealed that current GIS-based measures of ADS tend to calculate potential ADS instead of a realized one (Table 2). Also, we found no study including both spatial and non-spatial dimensions of ADS into one framework that could produce a more realistic score than current attempts in this direction. However, in a recent study performed in Iran, Kiani et al. (2017) developed an integrated measure of ADS by calculating a reasonable measure of actual travel time in contrast to previous reports that mainly focus on estimated potential travel time.
Table 2. Continued from previous page.

<table>
<thead>
<tr>
<th>Reference, country</th>
<th>Setting and study participant</th>
<th>Method employed</th>
<th>Indicators discussed</th>
<th>Component</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matsumoto et al., 2012 Japan</td>
<td>Dialysis facilities (88) Number of patients: 7,374</td>
<td>Travel time calculated by GIS in two models: the distance model (travel time to nearest facility) and the capacity-distance model (both travel time and facility capacity). The latter allowed facilities to accept the nearest patient (based on travel time) until capacity is full and then remit patients to the second-nearest facility run through facilities until all patients are accepted</td>
<td>Travel time, Facility capacity</td>
<td>Spatial accessibility</td>
<td>The distance model addresses only travel time to calculate spatial accessibility, while the capacity-distance model uses two ADS indicators jointly to calculate spatial accessibility. Potential travel time calculated instead of real travel time; no model considering non-spatial factors indicating a potential gap between calculated accessibility and real access, which is more than just the equity of travel time.</td>
</tr>
<tr>
<td>Judge et al., 2012 UK Renal Registry and England, UK local authority districts (354)</td>
<td></td>
<td>Multilevel Poisson regression models constructed separately for incidence and prevalence. Travel times and dialysis facilities catchment areas estimated by GIS; small area estimates of RRT prevalence produced for all 354 local districts.</td>
<td>Travel time, IMDm Spatial accessibility</td>
<td>Deprivation</td>
<td>Components not integrated into one ADS framework. Deprivation adjusted for socio-demographic differences but without adjusting is directly relative to NDS. Potential travel time calculated instead of real travel time.</td>
</tr>
<tr>
<td>Stephens et al., 2013 USA Centers for Medicare and Medicaid services (5,007) Number of patients: 332,117</td>
<td></td>
<td>Three data points estimated: (1) patients’ location; (2) location of dialysis facility currently serving patient; and (3) location of replacement facility. GIS-based calculation of travel impedance between them. Included calculations: 1. Travel impedance from patient location to current facility; 2. Travel impedance from patient location to replacement facility; 3. Incremental travel impedance for travel to replacement facility compared with travel to current facility.</td>
<td>Travel time Spatial accessibility</td>
<td></td>
<td>Actual data not obtained from each patient’s original dialysis facility. As it was assumed that patients utilize the closest location, potential accessibility was calculated Indication that facility capacity is a key indicator of spatial accessibility to dialysis facilities, but calculation of spatial accessibility not integrated with travel time. Non-spatial factors emphasized although not integrated with the spatial accessibility component to calculate a more realistic ADS.</td>
</tr>
<tr>
<td>Kiani et al., 2017 Iran Dialysis facilities (6) Number of patients: 168</td>
<td></td>
<td>Data for AAT and other spatial or non-spatial variables gathered via a semi-structured questionnaire for patients. Univariate analysis and univariate general linear model used to identify AAT associated factors. Driving time and distance calculated using Google maps; AAT of rural and urban analyzed separately.</td>
<td>Travel impedance Realized spatial accessibility</td>
<td>Non-spatial factors (sex, income level, caregivers, transportation mode, education level, ethnicity and personal vehicle ownership) influenced the revealed access identified in rural and urban groups but spatial factors were identified only in the former AAT calculated but some other important ADS indicators such as facility capacity was ignored.</td>
<td></td>
</tr>
</tbody>
</table>

4A scoring system developed by the British general practitioner Brian Jarman (b. 1933) for the level of social deprivation; 5measure of material deprivation within a population; 6an index of urban poverty published by the UK Department for Environment, Food and Rural Affairs designed to assess relative levels of deprivation in local authorities; 7Access to dialysis services; 8Need of dialysis services; 9Geographical information systems; 10Renal replacement therapy; 11Welsh index of multiple deprivation; 12Hemodialysis; 13Peritoneal dialysis; 14Two-step floating catchment area; 15index of multiple deprivation; 16AAT actual access time.
access owing to potential racial segregation (Saunders et al., 2014). However, both these studies calculated potential travel time. Meanwhile, many British studies (Roderick et al., 1999; Christie et al., 2003; White et al., 2006; Judge et al., 2012) emphasize the importance of non-spatial factors, e.g., Kiani et al.’s study (2017), considering deprivation as one of the main ADS indicators. Indeed, controversies in this field show a gap between calculated and real ADS. Although this study did not find any research integrating spatial and non-spatial factors into a GIS-embedded model for measuring ADS, various GIS-oriented studies join some spatial ADS indicators together to measure spatial accessibility (Yang et al., 2006; Matsumoto et al., 2012). For instance, Yang et al. compared two GIS-based methods, the 2SFCA approach and the kernel density method, in a case study on renal dialysis facilities in Chicago, USA. In this study, based on the main spatial ADS indicators travel time and facility capacity, the 2SFCA method produced better accessibility ratios overall (Yang et al., 2006). Although, this work only integrated spatial ADS dimensions, it has provided a platform that has been successfully used in other contexts, especially in primary healthcare where an overall measure including both spatial and non-spatial factors of access is included (Wang and Luo, 2005; Bagheri et al., 2008; McGrail and Humphreys, 2009; McGrail and Humphreys, 2015). For example, Bagheri et al. (2008) developed an integrated access to primary healthcare (APH) index which combined spatial accessibility, calculated by 2SFCA method, and a need index into one framework, while McGrail and Humphreys (2009, 2015) improved the 2SFCA method by introducing a concept based on three key components, i.e. spatial accessibility, population health needs and mobility.

The progress covered by this review, as well as the gaps revealed, raises the hypothesis that an integrated ADS index should calculate access more realistically than current GIS-based measures. However, further research examining whether this hypothesis is correct or not is needed. This mapping review provides some evidence-based recommendations that may help researchers and policymakers perform a primary study assessing this hypothesis. Three components of the 2SFCA platform should be addressed in order to construct an integrated ADS index, i.e. spatial accessibility, mobility and NDS.

Spatial accessibility must take into account both accessibility and availability. Travel time, discussed by most current studies, should be calculated as an indicator of accessibility with a threshold of 30 minutes as haemodialysis guidelines recommended (Mactier, 2007). However, actual travel time as proposed by Kiani et al. (Kiani et al., 2017) should be used together with facility capacity, expressed as the number of dialysis machines (supply) to the number of patients (demand) in each facility (Yang et al., 2006; Matsumoto et al., 2012) that seems to be the key availability indicator. It is as important as the travel time and should be incorporated into the 2SFCA framework with an appropriate threshold to construct catchment areas more realistically. Patients need dialysis thrice a week according to current haemodialysis guidelines (Mactier, 2007), which means that each machine can serve up to four patients per week (two patients on even days and two patients on odd days) leading to a supply-to-demand ratio threshold of ¼. If, regardless of this threshold, all catchments are constructed with a radius of 30 minutes travel time, some of them might include patients more than their facility capacity.

Mobility is defined as the population’s ability to overcome distance (Bishit et al., 2010). Taking the relative population size of those aged either <18 years or >75 years as the measure of reduced personal mobility, McGrail et al. (McGrail and Humphreys, 2009)

<table>
<thead>
<tr>
<th>Factors/Variables</th>
<th>Rate</th>
<th>Factors/Variables</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient age</td>
<td>14</td>
<td>Population density</td>
<td>2</td>
</tr>
<tr>
<td>Patient gender</td>
<td>11</td>
<td>Province need</td>
<td>2</td>
</tr>
<tr>
<td>Patient ethnicity</td>
<td>13</td>
<td>Nephrology beds</td>
<td>3</td>
</tr>
<tr>
<td>Patient’s education status</td>
<td>6</td>
<td>Location of the patient’s nephrologist</td>
<td>1</td>
</tr>
<tr>
<td>Marital status</td>
<td>1</td>
<td>Patient’s familiarity with facility</td>
<td>1</td>
</tr>
<tr>
<td>Patient’s income</td>
<td>9</td>
<td>Routine procedures at the facility</td>
<td>1</td>
</tr>
<tr>
<td>Patient’s employment status</td>
<td>5</td>
<td>Availability of transportation</td>
<td>3</td>
</tr>
<tr>
<td>Patient’s disability</td>
<td>1</td>
<td>Car ownership</td>
<td>23</td>
</tr>
<tr>
<td>Patient mobility</td>
<td>4</td>
<td>Road quality linking home and facility</td>
<td>4</td>
</tr>
<tr>
<td>Patient’s comorbidities</td>
<td>1</td>
<td>Transportation mode</td>
<td>3</td>
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<tr>
<td>Patient’s health insurance status</td>
<td>7</td>
<td>Travel cost</td>
<td>17</td>
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<tr>
<td>Home owner</td>
<td>1</td>
<td>Travel speed</td>
<td>1</td>
</tr>
<tr>
<td>Socioeconomic status of neighbourhood</td>
<td>1</td>
<td>Travel time</td>
<td>3</td>
</tr>
<tr>
<td>Location of dialysis patient’s residence</td>
<td>12</td>
<td>Travel distance</td>
<td>1</td>
</tr>
<tr>
<td>Language status</td>
<td>1</td>
<td>Time of the day for dialysis visit</td>
<td>1</td>
</tr>
<tr>
<td>Number of dialysis facilities</td>
<td>2</td>
<td>Degree of family support</td>
<td>3</td>
</tr>
<tr>
<td>Facility type (satellite or in-center)</td>
<td>4</td>
<td>Public assistance</td>
<td>1</td>
</tr>
<tr>
<td>Dialysis type needed*</td>
<td>2</td>
<td>Availability of human resources</td>
<td>1</td>
</tr>
<tr>
<td>Facility capacity</td>
<td>10</td>
<td>Deprivation</td>
<td>10</td>
</tr>
<tr>
<td>Number of dialysis consoles per facility</td>
<td>9</td>
<td>Climate conditions</td>
<td>1</td>
</tr>
<tr>
<td>Cost of care</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*haemodialysis (HD) or peritoneal dialysis (PD)
Conclusions

Current GIS-based measures of ADS tend to calculate potential ADS instead of a realized one and there is a need to examine whether an integrated index of ADS can calculate a realistic score. Listed factors affecting ADS are mainly non-spatial encouraging the design of an integrated ADS index produce better ADS score than those currently advocated. The mapping review strongly suggests exploring the hypothesis that a combined index of ADS including most dimensions of ADS can be developed and produce a better ADS score than current available. The 2SFCA method may be capable of providing a platform for this aim as the study recommended and researchers and policymakers are encouraged to examine and validate this hypothesis.

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