

ORIGINAL RESEARCH

Do rural and remote areas really have limited accessibility to health care? Geographic analysis of dialysis patients in Hiroshima, Japan

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ABSTRACT

Introduction: For an equitable distribution of health resources, resource-allocation policies focus on rural and also remote areas, assuming that these areas are underserved. However, definitions of 'rural' and 'remote' vary, and are not necessarily synonymous with 'underserved'. This Japanese study evaluated the association between the rurality/remoteness of the community in which a patient lives and his/her geographic accessibility to dialysis facilities.

Methods: Based on 1867 communities (census blocks) in Hiroshima Prefecture, Japan, predictive powers of five community-level rural/remote parameters (population size, population density, elderly rate, agriculture rate, and distance to the nearest city) were evaluated to identify communities where dialysis patients had a longer commute time to dialysis facilities. The proportion of low-access communities was examined when those communities were merged to form larger geographic units (four-level stepwise merger). One-way driving times of dialysis patients were used as the access parameter of a community and were calculated using geographic information systems based on the addresses of all the 7374 patients certified by municipalities as having renal disability, and on the addresses and capacities of all 98 dialysis facilities in Hiroshima.



Results: The average driving time was negatively correlated with population and population density, and positively correlated with elderly rate, agriculture rate, and distance to nearest city. When low-access was defined as >20, >30 & >40 min driving time, all rural/remote parameters showed better sensitivities (range 63.5-94.9%) than specificities (55.2-77.9%) to identify low-access communities, and positive predictive values were less than 50% for most parameters. When low-access was defined as >30 min driving time, the proportion of low-access communities substantially decreased when the geographic unit was expanded. In the administrative 'rural' area, the largest geographic unit, the percentage of low-access communities was 30%.

Conclusions: In any definition of 'rural/remote', and in any definition of 'low-access', the rural/remote areas contain a substantial proportion of high-access communities. In addition, a substantial proportion of low-access communities was excluded from rural/remote areas. The accuracy of the term 'low-access' deteriorated when the geographic unit of analysis was expanded. In order to identify underserved areas precisely, it is necessary to set the geographic unit of analysis as small as possible and measure the geographic accessibility itself, rather than designate some areas as 'rural' or 'remote', based on conventional geographic/demographic/distance parameters.

Key words: geographic information systems, health policy, Japan, renal dialysis, rural health services.

Introduction

Identifying medically underserved areas, in which people have less access to medical services than in other areas, is essential for planning policy that distributes health resources evenly. Traditionally, some areas have been labeled rural or remote based on available area variables, and subsequently seen as a focus of resource redistribution. Area variables often used for defining rural/remote are population size, population density, main industry, and distance to a large city¹⁻⁵. In Hiroshima Prefecture, Japan, for example, some municipalities (or parts of municipalities) are administratively designated rural based on their rate of population decrease, economic status, and industry structure. The prefecture government financially supports hospitals that cover rural areas and assigns doctors to these hospitals⁶. Different definitions of 'rural' are used in other countries for policy-making⁶. The rural/remote designation created by these definitions is a useful and convenient concept not only for health policy, but also for industry development policies and environmental resources management.

It is not clear, however, how much 'rural' overlaps with 'underserved'. There are several types of rural areas whose nature depends on the variables used for its definition, the cut-off point in

each variable, and the size of the geographical unit on which the definition is based^{3,4}. Even a rural area defined in a highly sophisticated manner can still contain areas that are not medically underserved. It is also possible that truly underserved communities are excluded from defined rural areas.

It is not easy to demonstrate how much geographic 'rural' overlaps with medical low-access. Although identifying rural areas is easy when the rural definition is clear, measuring accessibility for people in these areas is quite difficult. In order to measure access to health care, it is necessary to know who had what diseases and how far is it between the community and each facility to which the patients must commute. It is unusual to have such data in a complete form. In patients with some diseases, however, access data can be obtained from public registration systems.

Therefore, this study focused on hemodialysis patients in Hiroshima Prefecture, and evaluated the association between the rurality of the community in which a patient lives and his/her geographic accessibility to dialysis facilities. Dialysis patients usually need to undergo treatment three times a week, and access data of all dialysis patients in the prefecture is available from the municipal registration system. Thus, to what degree 'rural' and 'remote' areas (defined by community-level parameters) actually accords with 'low-



access' areas (defined by driving time of dialysis patients) can be determined. Also demonstrated is how the accuracy of the term 'low-access' changes when the size of a geographic unit in analysis is expanded. Based on the results of the analyses, the extent to which the concepts rural and remote can be used to develop effective outreach strategies to underserved populations is revealed.

Methods

Study area

Hiroshima, one of the 47 prefectures in Japan, is located in the western part of the country (Fig1). Its population was 2 860 750 according to the 2011 census. For area-based analysis, the second-smallest census block (community) was used as the geographic unit smaller than a municipality (city, town or village). There are 1869 communities in Hiroshima, and two communities were excluded due to lack of age-group population data. In this study, data on all the communities, dialysis patients, and dialysis facilities in Hiroshima Prefecture were used for analyses.

Community-level rurality/remoteness and accessibility parameters

Data on community-level population, area, and the number of primary industry workers were obtained from the 2005 National Census. Primary industries are agriculture, forestry, and fisheries according to the Japan standard industrial classification⁷.

The following five variables were employed as community-level rural/remote parameters: (i) population size; (ii) population density (/km²); (iii) elderly rate (proportion of residents aged ≥ 65 years); (iv) agriculture rate (proportion of primary industry workers among the residents ≥ 15 -years); (v) distance to the nearest city with population $> 50\,000$. Population size, population density, elderly rate and agriculture rate were used as rural-ness parameters, and distance to the nearest city was the remoteness parameter, based on various Japanese and international rural definitions^{1-4,6,8-10}.

Distance to the nearest city was calculated as driving minutes between the centroid point of a community and the city hall of the nearest city with population $> 50\,000$. In this process, network analysis was conducted (ie the shortest travel-path was discerned between two locations on a road network including highways), to find the travel time (in min) by car using geographic information systems (GIS) software ArcGIS v10.0 (<http://www.esri.com/products/arcgis/>) and ArcGIS Data Collection Road Network 2011 (<http://www.esri.com/products/data/data-collection/>). In the latter, the driving speeds of all road segments were classified into 14 categories, according to the type and width of the segment.

As a community-level accessibility parameter, the average one-way driving time (in min) of dialysis patients in the community was employed. Details of the data collection and calculation methods are shown in the next section.

Dialysis patients, facilities, and calculation of driving time

Collection of location information on dialysis patients and dialysis facilities has been described previously^{11,12}. Briefly, postal code information as of August 2011 of all the 7374 patients certified by municipality governments as having first or third grade 'renal disability' were collected (capture rate 100%). Information on postal code and the maximum number of outpatients (capacity) of all 98 dialysis facilities was also collected (capture rate 100%). For a person to be certified as having renal disability, the serum creatinine level must be higher than 5.0 mg/dL or creatinine clearance less than 20 mL/min¹³. Most patients with renal disease in Japan apply for certification of renal disability when they begin dialysis therapy in order to obtain public financial assistance for the medical treatment. As a preliminary survey, the certified disability status among all the dialysis patients was checked as of June 2011 at seven randomly sampled medical institutions in Hiroshima. Of the 486 dialysis patients, 483 (99.3%) were certified as having a first- or third-grade renal disability¹¹.



For each dialysis patient, one-way driving time to the nearest available facility was calculated in the capacity–distance model^{11,12}. First, patients and facilities were geocoded in GIS according to their addresses. Next, the shortest road-driving minutes for each patient was calculated based on an algorithm programmed for this study. In the algorithm, each facility accepted patients in order of shorter travel time until it reached the limit of its capacity. If a patient was not accepted by the facility in the first step, the patient approached the next-nearest facility in the same manner. The first and second steps were followed until all patients were accepted by one of the facilities. The process was conducted based on the network analysis.

Among the 1867 communities included in this study, 497 did not contain any dialysis patients. However, driving time needed to be calculated for these communities as well as those with dialysis patients. Thus, the shortest travel time between the centroid point of each of the communities and its nearest available facility was calculated as the patient driving time in the community. The nearest available facility was identified in the capacity–distance model in which the request from each no-patient community did not occupy the facility capacity.

Analysis

Correlation analysis was conducted between the rural/remote parameters and the access parameter. Most of the parameters have a skewed distribution in values, so Spearman's rank correlation coefficient was employed.

Next, receiver operating characteristic (ROC) analysis was conducted to evaluate the predictive power of rural/remote to identify low access areas. Communities were dichotomized into low-access and high-access, according to the average driving time of dialysis patients in each community. Three degrees of low-access category were then created by setting the cut-off point for driving time at 20, 30, and 40 min. The 30 min interval was used because most past studies on geographic accessibility to dialysis therapy have used this value¹⁴⁻¹⁶; values 10 min shorter and longer were then added.

Sensitivity, specificity, positive predictive value, negative predictive value, and area under curve were calculated for each rural/remote definition with regard to its power to identify the low access area defined at each driving time cut-off. The optimal cut-off value of each parameter was determined using the Youden Index¹⁷. Area under curve was calculated using the Delong method¹⁸.

The predictive power was evaluated not only for each parameter but also for combinations of all the five parameters. For this purpose, a multivariate logistic regression equation was formulated, and the optimal sensitivity and specificity of the combination were calculated. Based on the maximum likelihood method, following logistic regression equation was built:

$$\text{Probability (low-access)} = 1/[1 + \exp(-X)], \text{ where } X = -3.912899 - 0.0000584 * (\text{population}) - 0.0002194 * (\text{population density in /km}^2) + 0.0116272 * (\text{agriculture rate in \%}) + 0.0047531 * (\text{elderly rate in \%}) + 0.0586207 * (\text{distance to nearest city in min}).$$

The equation provides the best estimate of a community's likelihood of being low access expressed as a probability between 0.0 and 1.0. All five parameters were used in the regression equation as continuous variables. This method has been utilized, for example, to examine the combined power of multiple risk factors to predict diabetes^{19,20}.

Finally the effect was examined of expanding the geographic unit on the proportion of low-access communities within the unit. Four levels of geographic unit were used: (i) community; (ii) municipality; (iii) secondary healthcare area (*niji-iryo-ken*); and (iv) administrative 'rural' area (*chusankan-chi*). The area and population sizes increase in this order. Hiroshima Prefecture consists of 1869 communities, 35 municipalities, 7 secondary healthcare areas, and two administrative 'rural'/'urban' areas. The administrative rural area is defined by combination of five national laws and has been used for resource redistribution policies in the prefecture (as mentioned in the Introduction). The five national laws are the *Mountain Village Activation Act 2011*, the



Isolated Island Activation Act 2012, the Peninsular Areas Development Act 2012, the Act on Special Measures for Promotion for Independence for Underpopulated Areas 2012, and the Act on the Promotion of the Improvement of Basic Conditions of Agriculture, Forestry and Other Business in Hilly and Mountainous Areas 2011.

Descriptive statistics and correlation analysis were conducted with IBM SPSS Statistics v21 (<http://www-01.ibm.com/software/jp/analytics/spss/products/statistics/>). The ROC analysis was performed with MedCalc v12 (<http://www.medcalc.org/>). Logistic regression analysis was done with STATA v12.1 (<http://www.stata.com/>).

Ethics approval

Patient data in this study was collected by local governments and used in an anonymous form with permissions from the governments. This study was approved as a study that can be conducted without individual informed consent by the Ethics Committee of Epidemiological Research, Hiroshima University (Epi-412).

Results

The study area is shown (Figs1,2). Basic statistics of the 1867 communities are given (Table 1). In 75% of these communities, dialysis patients live within a 20 min drive of their treating facility.

Results of correlation analysis between a rural/remote parameter and the average driving time of dialysis patients are shown (Table 2). Driving time was negatively correlated with population and population density, and positively correlated with elderly rate, agriculture rate, and distance to nearest city.

Results of ROC analysis are shown (Table 3). Low-access levels were defined as >20 min, >30 min and >40 min driving time. At each level, rural/remote parameters showed good sensitivities. Most specificities, however, were lower than the sensitivities, and as a consequence, positive predictive values were less than 50% in most of the parameters.

Changing the level of 'low access' had a moderate impact on sensitivities and specificities (Table 3). Sensitivities in all the five parameters increased and specificities in four parameters slightly decreased when the cut-off of driving time for 'low access' increased from 20 min to 40 min. However, the sensitivity and specificity in the 'all' parameter and area under curves were stable throughout the three levels of 'low access'. Positive predictive values decreased and negative predictive values increased when the cut-off increased, reflecting the decrease in the proportion of 'low access' communities among all communities. Overall, the level of 'low access' did not have a large impact on the predictive power of each parameter.

The effects of expansion of geographic unit are shown (Fig3). Here, low-access was defined as >30 min driving time. The proportion of low-access communities within a boundary substantially changed when municipalities were merged into secondary healthcare areas (Fig3a,3b). Among the municipalities, the proportion of population living in the low-access communities among the entire population ranged from 0 to 100%. When the geographic unit was expanded to secondary healthcare area, the proportion ranged from 0.9% to 19.9%. This means the expanded border is less accurate in demarcating low-access population than the original version. In the administrative rural area, which is medically and financially supported by the prefecture government due to its 'underservedness', the proportion was 30%.

Discussion

The rural/remote parameters examined in this study correlated well with geographic accessibility to dialysis facilities. By setting an optimal cut-off value, each parameter or combination of parameters seemed to work as a predictor of low-access areas. However, in any definition of rural/remote, and in any definition of low-access, a substantial proportion of low-access communities was excluded from rural areas. In addition, a large number of high-access communities was included in rural areas. Furthermore, the accuracy of the term low-access deteriorated markedly when the geographic unit expanded.

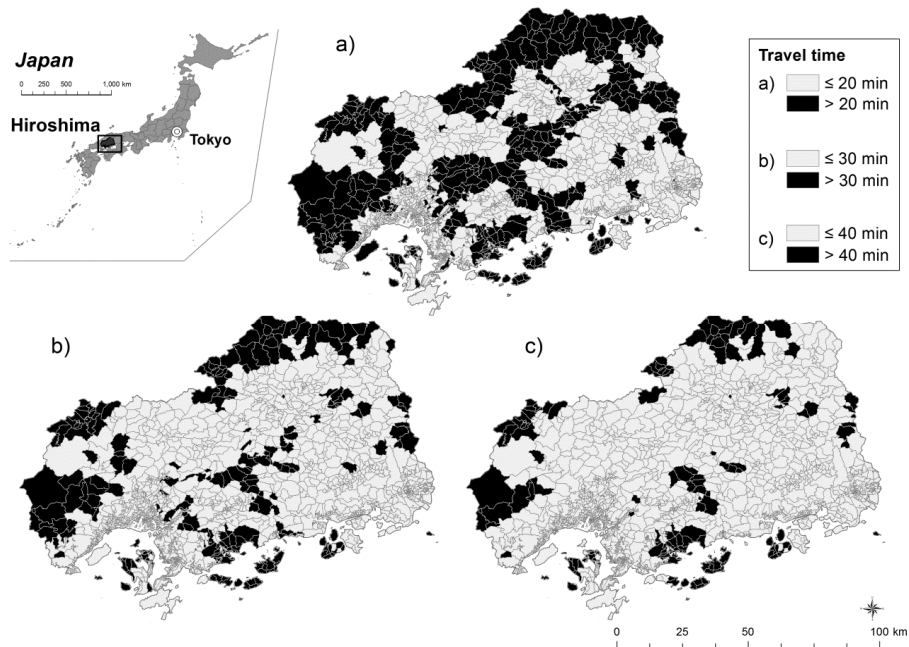


Figure 1: Hiroshima prefecture and its communities (census blocks) classified according to driving time to the nearest available dialysis facility.

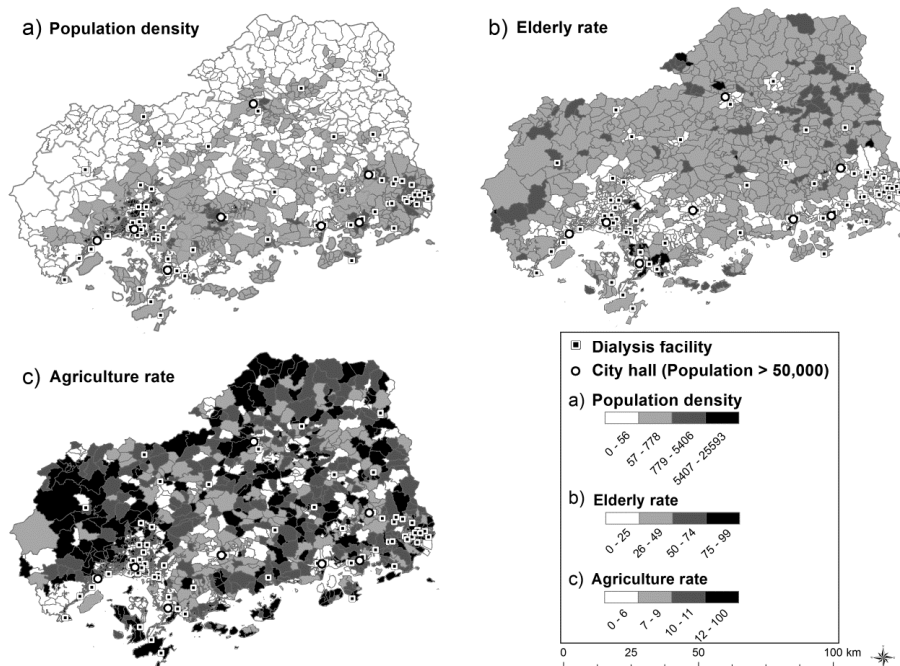


Figure 2: Hiroshima prefecture and its communities (census blocks) classified according to rural parameters.

Table 1: Characteristics of the communities studied (N=1867)



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	Unit	Median	IQR
Population		782	290 - 1843
Area	km ²	1.0	0.2 - 5.6
Population density	per km ²	1201.1	77.1 - 5693.8
Elderly rate	%	26.6	18.4 - 36.5
Agriculture rate	%	2.0	0.2 - 17.8
Dialysis patients		2	0 - 5
Distance to nearest city *	driving minutes	23.1	13.8 - 37.2
Distance to dialysis facility **		n	[%]
>20 minutes		457	[24.5]
>30 minutes		253	[13.6]
>40 minutes		154	[8.2]

* Distance to the nearest city with population more than 50,000

** Distance to the nearest available dialysis facility

Table 2: Correlation between travel time of dialysis patients and community rural/remote parameter (N=1867)

	Correlation coefficient *	P
Population	-0.268	<0.001
Population density	-0.578	<0.001
Elderly rate	0.388	<0.001
Agriculture rate	0.563	<0.001
Distance to nearest city	0.586	<0.001

* Spearman's rank correlation coefficient

The results suggest that no matter how carefully rural parameters are used, it is not possible to perfectly identify low-access areas. More precisely, where these areas are can only be speculated upon. The size of geographic unit determines the extent to which an area can be described as

'low-access'. Policy-makers may need to take into account the limitations of the rural definition and the geographic unit when they make a decision on rural health policies^{1,3,4}.



Table 3: Optimal cut-off value and predictive power of rural/remote parameter to identify low access communities defined as >20, >30, >40 min driving time to dialysis facility

		Cut-off	Sensitivity	Specificity	PPV%	NPV%	AUC
>20 mins	Population	≤733	67.0	57.5	33.8	84.3	0.67
	Population density	≤350.1	80.1	72.6	48.6	91.8	0.82
	Elderly rate	>32.6	63.5	73.5	43.7	86.1	0.74
	Agriculture rate	>3.9	81.6	69.0	46.0	92.0	0.81
	Distance*	>23.3	91.5	64.2	45.3	95.9	0.83
	All**		88.0	69.0	47.8	94.7	0.85
>30 mins	Population	≤731	73.5	55.5	20.6	93.0	0.69
	Population density	≤411.8	86.2	65.2	28.0	96.8	0.82
	Elderly rate	>32.7	71.1	70.1	27.2	93.9	0.76
	Agriculture rate	>3.1	89.7	61.7	26.9	97.5	0.81
	Distance*	>26.9	94.9	67.2	31.2	98.8	0.87
	All**		92.8	68.3	31.3	98.4	0.87
>40 mins	Population	≤710	79.2	55.2	13.7	96.7	0.71
	Population density	≤411.8	88.3	62.5	17.5	98.3	0.81
	Elderly rate	>27.4	90.7	56.6	15.8	98.5	0.81
	Agriculture rate	>5.2	89.0	63.8	18.1	98.5	0.83
	Distance*	>30.4	92.2	69.8	21.5	99.0	0.89
	All**		86.7	77.9	25.7	98.5	0.90

PPV: positive predictive value; NPV: negative predictive value; AUC: area under curve

*Driving minutes to the nearest city with population >50,000

**Multiple logistic regression model including all the parameters as explanatory variables

There has been an attempt to create a universally applicable definition of what constitutes rurality⁸. In practical terms, however, each country uses a different definition of what is rural, and this makes rural health research difficult at an international level^{21,22}. The USA, England, Canada and Australia have their own definitions of 'rural', so researchers in these countries study rural health on the basis of those definitions^{1-4,9}. Even within a country, there is no uniform definition of what is rural. In the USA, for example, there are several such definitions^{3,23}. Some health services and epidemiological studies have shown that differences in rural definitions create a critical difference in study results²⁴⁻²⁶. Many researchers and policy analysts have acknowledged this,

and agree that the choice of a definition depends on the purpose for which it is used^{1,3,4}.

The subjects of this study are limited to dialysis patients in Hiroshima Prefecture. The direct application of the results is therefore limited to this part of Japan. If patients with other diseases or in other areas had been studied, the results would have been different. Primary-care facilities, for example, would have been distributed more equitably than dialysis facilities²⁷. Moreover, the cut-off values for a 'long' commuting time are arbitrary. The results of this study should thus be applied cautiously to other settings

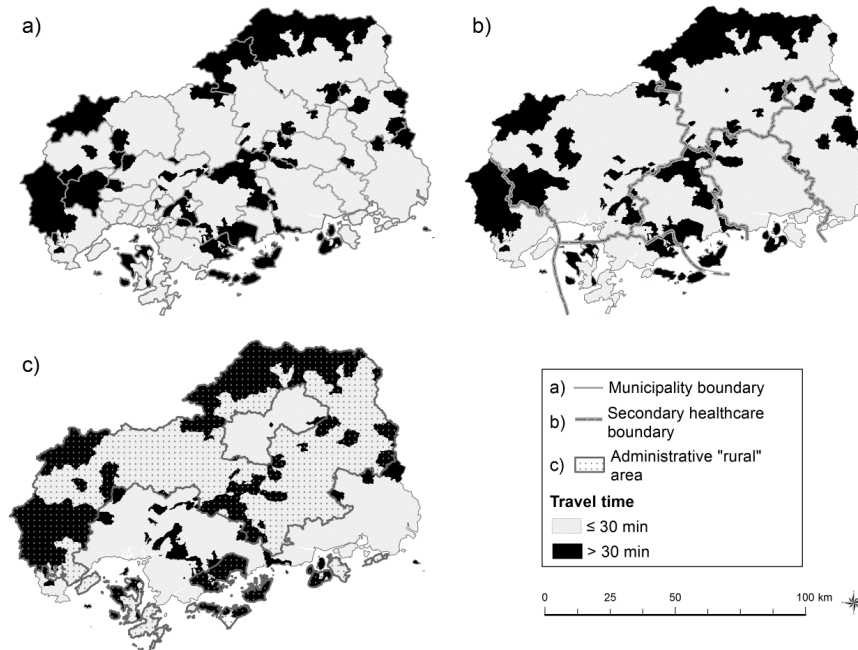


Figure 3: Effects of expansion of the geographic unit: (a) Low-access communities (>30 min) within each municipality; (b) secondary healthcare area; and (c) administrative rural border.

Dialysis costs more than treatment modalities for other chronic diseases so the economic status of a patient can influence his or her access^{28,29}. In Japan, however, the financial burden of dialysis therapy for patients has been minimized. In addition to universal health insurance coverage supported by the government^{30,31}, there is special public financial support available for those certified as 'renal disabled'. With the support system, the co-payment for dialysis therapy for a 'renal disabled' patient is totally exempted or reduced to ¥10,000 (US\$100) per month, depending on household income.

The concept of access incorporates financial accessibility, health resource availability and geographic accessibility³². The commuting time used in this study cannot be equated with access, but remains a part of it. However, as mentioned above, patients with end-stage renal disease in Japan have very limited financial barriers to dialysis care. Therefore the availability of human and material dialysis resources and the

distance to those resources (both which were measured and included in the concept 'commuting time' in this study), are critical in determining dialysis patients' access to dialysis facilities.

All certified renal disabled people in Hiroshima were included^{11,12}, and the authors' preliminary survey demonstrated that almost all dialysis patients in the prefecture were certified renal disabled. According to the annual report of the Japanese Society for Dialysis Therapy, 7132 patients in Hiroshima were receiving dialysis in 2010³³, which is close to this study's 7374 patients.

The distribution of patients in this study may be biased by the unique nature of dialysis care in Japan. Dialysis patients in rural areas can relocate to urban areas in order to shorten their commuting time to the dialysis facility, because commuting is literally a matter of life and death. The authors have previously reported, based on the same data, that the



prevalence of dialysis patients was lower among rural/remote residents than among urban residents, which suggests that relocation of dialysis patients did occur¹².

Past studies have suggested the usefulness of GIS as a model for calculating commuting time of dialysis patients^{14-16,34-36}. Conventional models, however, assume that a patient commutes to the nearest facility in linear or road distance^{14,34-36}. These models are likely to overestimate the geographic accessibility of patients. The capacity–distance model used in this study incorporated both geographic accessibility and facility capacity^{11,12}. The model can simulate access of patients in a more realistic manner than the model without facility capacity³⁷. The capacity–distance model has potential to be applied to people in other parts of the world whose medical conditions require regular commuting.

The geographic unit used in this study is the second-smallest census block. Municipality, secondary healthcare area, and prefecture have often been used as geographic units in policy analyses in Japan³⁸⁻⁴². The census block is the smallest available geographic unit that can be connected to census data. There are more than 1800 census blocks in Hiroshima. The use of census blocks enabled the present study's analysis of the distribution of low access areas to be more precise than for municipalities ($n=35$), secondary healthcare areas ($n=7$) or administrative rural/urban areas ($n=2$).

Conclusion

In order to distribute health resource equitably and efficiently, policy-makers need to accurately identify underserved areas. For the construction of data that can be used for such outreach policies, it is necessary to measure access itself and find true low-access areas, rather than, as a surrogate, to designate some areas as rural or remote based on conventional geographic, demographic, economic and distance parameters. The geographic unit of analysis should be as small as possible. In analysis for prefecture-level policy-making, census blocks or even smaller areas are suitable as the unit, rather than the municipality and secondary healthcare area that have been used traditionally.

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