Examining geographical accessibility to multi-tier hospital care services for the elderly: A focus on spatial equity

Abstract

Background: With the rapid demographic shift towards an ageing society, it is a concerted effort to facilitate elderly's access to healthcare in order to maintain and improve their quality of life. In China, hospital care services dominate the healthcare market, which requires a better understanding of accessibility to hospitals in order to rationally allocate resources in spatial and land use planning. However, little attention has been paid to analysing the geographical accessibility to hospitals specific to the elderly population.

Objectives: The objective of this study is to examine the spatial access to multi-tier – primary, secondary, and tertiary – hospital care services for older adults with an explicit focus on equity – the (un)even distribution of geographical accessibility.

Methods: Building on the revealed travel patterns of elderly's medical trips, this study measures the level of accessibility at the sub-district level and assesses the inter- and intra-district disparities in Nanjing, China. To this end, we draw on the city's GIS database and the 2015 Nanjing Travel Survey. A two-step floating catchment area method was utilised to measure accessibility and the Gini coefficient was applied to show inequity.

Results: It is found that spatial distribution plays a significant role in the accessibility to hospital services. Upper-tier hospitals are more aggregated and thus more unevenly accessible than the lower-tiers. In addition, accessibility to different tiers of hospitals varies greatly throughout the city, with pockets of deprived access identified on the outskirts. Imbalance and inequality of access to hospitals are also present within districts, displaying an increasing trend from the city centre to periphery.

Conclusions: These empirical findings provide insights for health interventions in order to improve equitable access and rational allocation of health resources. This paper also bears relevance for strategically advancing the hierarchical healthcare systems in China from a geographical perspective.

Keywords: Elderly people; Multi-tier hospitals; Geographical accessibility; Healthcare equity; Two-step floating catchment area method; Nanjing (China)

1. Introduction

The declined fertility over the past decades along with increased lifespans is causing a significant shift in the distribution of Chinese population towards older ages (Cheng et al., 2019b; World Health Organization, 2016). At the end of 2017, elderly people (aged 60 and over) consisted of 16.2% (229 million) of the total Chinese population (United Nations, 2017). This proportion is projected to rise to 25.3% in 2030 and 35.1% in 2050 (United Nations, 2015, 2017). As the population ages, age-related chronic diseases, e.g. heart disease, stroke, arthritis, and cancer, are more likely to occur (Prince et al., 2015). The rising number of elderly people, in combination with the growing risks of chronic diseases, poses a range of challenges to the provision of healthcare services. In order to identify under-served areas and suggest informed allocation of healthcare resources, it is essential to examine spatial variations in access to hospital care among elderly population. [1]

Accessibility to healthcare is recognised as a fundamental facilitator of the elderly's overall health and quality of life (Dewulf et al., 2013; Widener and Hatzopoulou, 2016). Spatial barriers for elderly people to reach healthcare facilities result in their reduced uptake of disease-prevention services and lower utilisation of healthcare services (Cvitkovich and Wister, 2001; Hiscock et al., 2008). More importantly, relative to younger people, inequities in healthcare access are exacerbated for elderly people who are more likely to have poorer health status and limited mobility options (e.g. walking difficulties and driving reduction/cessation). Equity in accessibility has received growing attention, with many researchers using accessibility to appraise social and transport inequality (Cheng et al., 2019a; Lucas et al., 2016; Ricciardi et al., 2015). The basic idea is that healthcare service and infrastructure investments should target the dependent and vulnerable people, such as older residents, in addition to improving the overall accessibility across urban spaces.

Ensuring adequate and equitable access to healthcare for elderly population is a concern of increasing importance for policymakers to build an age-friendly society. Over the past decade, quite several empirical studies have investigated elderly's spatial access to healthcare services ranging from primary care to speciality care, conducted in the US (Jin et al., 2018; Zhang et al., 2018), Australia (Evans et al., 2017; Zainab et al., 2015), Singapore (Deborah et al., 2018), and Japan (Hanibuchi et al., 2011). As far as we know, no such research is contextualised in China, where residents' health-seeking behaviour is of specific importance. Chinese hospitals are categorised into three tiers – primary, secondary, and tertiary – providing different qualities and types of services (Pan et al., 2016; Zhang et al., 2019).[2] However, hospital services are not delivered through this multi-tier system in line with a gatekeeping and two-directional referral network (Yu et al., 2017; Zhang et al., 2019). Upper-tier (such as secondary and tertiary) hospitals

[1] Access to healthcare is a multi-dimensional concept which can be understood from spatial and non-spatial (e.g. social, cultural, and economic) perspectives (Wang and Luo, 2005). This study pivots on spatial factors – geographical accessibility – on examining elderly's access to healthcare.

[2] The primary hospital is a small healthcare centre at community level and primarily sought out for general health conditions. The secondary hospital is a medium-sized regional healthcare centre covering several communities and takes teaching and research responsibilities besides health and medical services. The tertiary hospital is the most sophisticated with multiple differentiated departments, offering specialised healthcare services for residents from different regions and undertaking higher education and research tasks. In general, service capacity (e.g. number of physicians, equipment, and hospital beds) and quality (e.g. assurance and reliability) increases from primary, secondary to tertiary hospitals.

also provide primary care, and residents have much freedom of accessing upper-tier hospitals to receive first diagnosis and treatment services. Simply focusing on primary care or speciality care services may produce a biased understanding of residents' access to healthcare resources in China. Against this backdrop, this study investigates the geographical accessibility to multi-tier hospital care services for elderly people with an explicit focus on spatial equity, i.e. the (un)even distribution of accessibility.

The contribution of this research to the literature is threefold. First, we comprehensively evaluate the geographical accessibility to multi-tier hospital services, which is valuable for the planning and development of hierarchical healthcare systems in China. Second, we employ empirically-based distance thresholds – revealed by realised travel behaviour patterns of elderly's medical trips – for calculating the level of accessibility, which is important for accurately identifying healthcare shortage areas. Third, we measure the inter- and intra-district equity in accessibility to hospitals, which provides a useful reference for optimising the spatial layout of health facilities.

The remaining of this paper is organised as follows. Section 2 reviews previous studies on healthcare accessibility for elderly people. Section 3 discusses the collected data in the Nanjing (China) case study, followed by Section 4 in which research methodology is described. In Section 5 we elaborate on the results regarding accessibility landscape of multi-tier hospital services and equity in the spatial distribution, while a discussion and conclusion are provided in Section 6.

2. Literature review

The concept of accessibility has been deep-seated in transport geography to evaluate the quality and extent of which transport systems enable people to reach potential opportunities (Handy and Niemeier, 1997; Hansen, 1959). It helps to unravel the complicated relationships between land use, transport and human activities. In health research, accessibility mediates individuals' environment exposure and health behaviours/outcomes (Perchoux et al., 2013). In regard to healthcare, accessibility is of great significance to manage healthcare provisions for reducing inequities in health outcomes of population segments. Geographical accessibility to healthcare refers to the ease with which individuals are able to reach healthcare services and is basically measured using GIS-based techniques. It focuses on the role of geographical distances in the interactions between population demands and healthcare services (Langford and Higgs, 2006; Mao and Nekorchuk, 2013). Multiple measurement methods of healthcare accessibility have been developed in the literature, including travel distance or time, provider-to-population ratio (PPR), gravity models (and its derivatives, e.g. two-step floating catchment area method), and kernel density estimation (KDE). For a comprehensive review of measurements for healthcare accessibility, we refer to Guagliardo (2004), Wang (2012), and Neutens (2015).

Accessibility is one of the key elements in seeking healthcare services among elderly population, from primary (Evans et al., 2017) to speciality care (Zainab et al., 2015). Many healthcare disparities are the result of the uneven geographical distribution of population, healthcare facilities, and the transport system between them (Messinger-Rapport, 2009). Various policies – including public transit service (Yuan et al., 2019), pedestrian environment (Cheng et al., 2019c; Loo and Lam, 2012), car or van ride (Jin et al., 2018), and social support (Zhang et al., 2018) – have been considered in order to reduce spatial barriers for elderly population. For example, Zainab et al. (2015) describe the importance of public transit for elderly people to improve utilisation of dental care in Sydney. From a microscale perspective, Loo and Lam (2012) assess the geographical accessibility, in particular walkability concerning convenience, comfort, and safety, around healthcare facilities for older adults in Hong Kong. They highlighted the provision of a walkable pedestrian environment in order to promote active ageing. Jin et al. (2018) and Zhang et al. (2018) simulate a 'real world' community-based program in Manhattan, New York City, and find that social support is able to improve elderly's healthcare accessibility. Social support helps to overcome spatial barriers and arouse higher awareness of – and participation in – health activities.

Equity in elderly's healthcare accessibility has also received much research attention. Tao and Cheng (2019) show the uneven distribution of geographical accessibility to healthcare for older adults in Beijing, where the level of accessibility decreases significantly from the central area outwards. They also find that older people are disadvantaged in the competition with younger people for healthcare services. Wu and Tseng (2018) evaluate disparities in elderly's community care services using a geographical accessibility and inequity index, suggesting that policy appraisals should not only measure overall accessibility but also aim for a more equitable distribution. Cheng et al. (2012) note that geographical accessibility helps to identify healthcare shortage areas and inform an equitable allocation of resources. Multiple approaches have been developed to measure equity in healthcare accessibility, ranging from simple economic indicators to complicated spatial models. For instance, the spatial disparity between the population and physicians in Japan is analysed using Lorenz curves and Gini coefficients (Shinjo and Aramaki, 2012). Inequality in the spatial distribution of medical facilities in China is examined by the Theil index (Yin et al., 2018). The disparity in the geographical distribution of clinics in the metropolitan city of Daejeon, South Korea is measured by hot-spot analysis (Lee, 2013). Spatio-temporal disparity of public healthcare resources across China over 2003-2015 is analysed by the Moran's I model and the dynamic spatial Durbin panel model (Song et al., 2019). Although the literature has contributed to the understanding of spatial disparity of healthcare for older adults, few studies have investigated the spatial equity in the distribution of access to multi-tier hospital services in China.

3. Data

In this research we use Nanjing, a Chinese mega-city with a population of 8.2 million (in 2015), as a case study. Nanjing is the economic, educational, and transport hub of eastern China. In recent years, Nanjing is believed to be one of the most rapidly growing cities in China with GDP exceeding 156 billion in 2015 and an annual growth rate over 8.0%. In 2015, 21% of the Nanjing residents were aged 60 or older and the proportion is projected to increase to 30% by 2030. The important economic and demographic status of Nanjing makes it an interesting area for measuring accessibility for elderly people. The administrative division (eleven districts) of this city is presented in Figure 1. Generally speaking, city urban areas consist of Gulou, Xuanwu, Jianye, Qinhuai, and Yuhuatai Districts while the other six are suburban districts. The entire city is partitioned into 117 sub-districts, which are the basic territorial units for urban governance and administration.[3] Analysis of hospital care accessibility is conducted at this sub-district level.

[3] The administrative division of Chinese cities is three-level: city – district (county) – sub-district (township). Although a sub-district (town) can be sub-divided into several residential communities or villagers' groups, these subdivisions are autonomy and do not have much importance in administrative power.

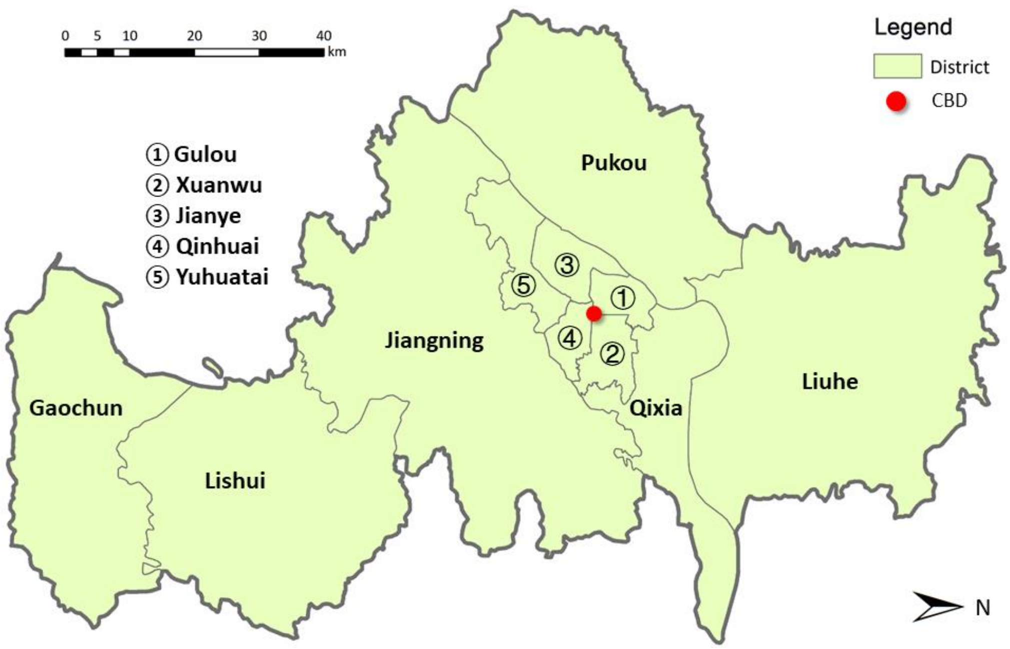

Figure 1. Study area in Nanjing, China

For this study, we use two city-wide data sources to analyse hospital accessibility. The first is the 2015 Nanjing Travel Survey (NTS2015) carried out by the Nanjing Municipal Bureau of Urban Planning (Nanjing Institute of City and Transport Planning, 2016). To make informed policies on improving access to hospitals for older residents, we need to understand how older adults travel to hospital services. An analysis of the NTS2015 offers the best available dataset for investigating the travel characteristics of medical trips to hospitals among Nanjing's elderly population. This survey was conducted via face-to-face household interviews on a typical weekday (Wednesday, 28-Oct-2015) and approached almost 35,600 individuals from 12,000 households. It collected information about each trip including origin and destination, mode choice, starting and ending times, and purpose. A total of 7,460 elderly respondents (aged 60 and over) are included in the database. Among them, 275 had performed 318 medical trips to hospitals on the reference travel day.

The second data source is the Nanjing city GIS database. It includes the information of hospitals (e.g. address, tier, and number of physicians and beds) and the population data (e.g. number of elderly and younger people) at the sub-district level at the end of 2015. Figure 2 provides the spatial distribution of multi-tier hospitals and elderly population density at the sub-district level. Elderly people are unevenly distributed, showing a decreasing pattern of population density outwards from the city centre. The highest elderly population density is 10,965 persons/km^2 at the Wulaocun Community of Qinhuai District, while the lowest density is just 30 persons/km^2 at the Shiqiu Community of Lishui District. The significant variation in the elderly population density (SD = 2,111 persons/km^2) requires the sensible allocation of hospital services. There are 139 hospitals in total – primary (71), secondary (43), and tertiary (25) – with varied service capacities shown in Table 1. The tertiary hospitals generally provide the highest capacity with the mean number of physicians of 470 and the mean number of hospital beds of 1,107. We note that upper-tier hospitals are more spatially aggregated in the city centre than lower-tier hospitals.

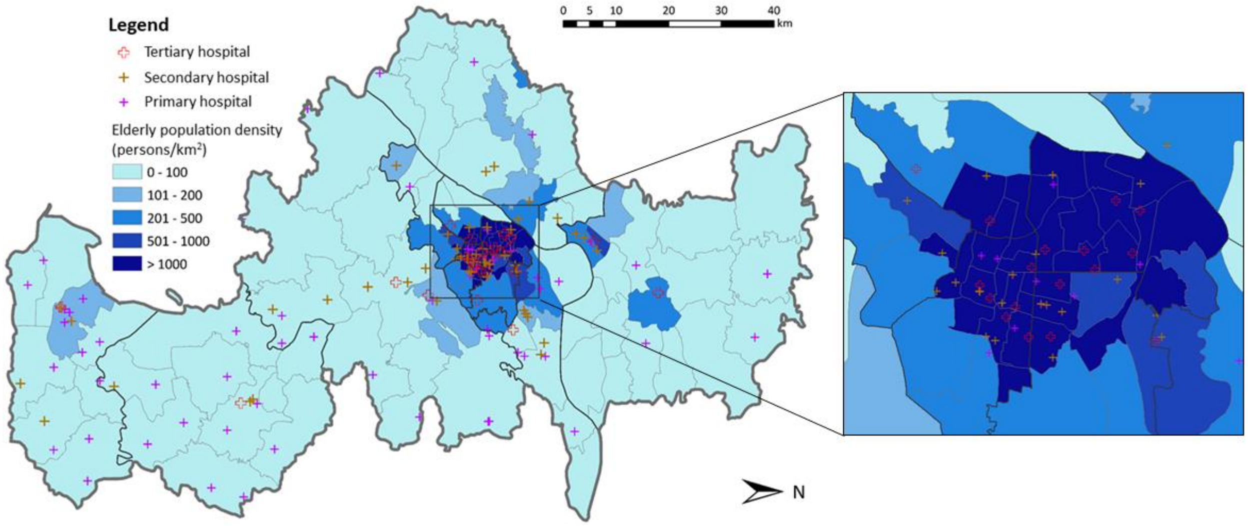

Figure 2. The spatial distribution of hospitals and elderly population density

Table 1 provides the general travel pattern of medical trips to hospitals made by elderly respondents. The average travel time to healthcare services was 40.6 min. We geocoded the origin and destination of each medical trip using the Baidu API services for measuring travel distance along the street network. It can be seen that the average travel distance was 7.9 km and median travel distance (the 2nd quartile) was 7.0 km. Three major travel modes were identified for medical trips: public transit (PT) including metro and bus (46.2%), car including private car and taxi (31.0%), and walking (14.1%). Table 1 also presents the travel characteristics varied by the tier of hospitals. In general, older respondent accessing tertiary hospitals performed the longest trips concerning both time and distance travelled. For example, the average travel distance to tertiary hospitals was 11.8 km, which was 6.5 times the distance to primary hospitals (1.8 km). In terms of travel mode used, walking accounted for the largest share (59.6%) of primary hospital trips, while elderly people's visits to tertiary hospitals were more made by public transit (48.7%). Car witnessed an increasing usage from primary (9.6%), secondary (31.0%) to tertiary (35.8%) hospitals.

Table 1. Service capacity of hospital care and travel characteristics of elderly's medical trips

Characteristics	All	Primary	Secondary	Tertiary
Hospital service capacity				
Number of hospitals	139	71	43	25
Mean number of physicians	127	20	119	470
Mean number of beds	266	32	202	1107
Travel characteristics				
Number of trips	318	42	64	212
Mean travel time (min)	40.6	20.8	32.5	52.7
Distance travelled (km)				
Mean	7.9	1.8	5.3	11.8
1st quartile	2.5	1.3	2.8	4.2
2nd quartile (median)	7.0	2.3	4.8	10.4
3rd quartile	11.2	3.0	8.5	15.6
Major modes of travel (%)	PT (46.2)	Walking (59.6)	PT (53.6)	PT (48.7)
	Car (31.0)	PT (23.1)	Car (31.0)	Car (35.8)
	Walking (14.1)	Car (9.6)	Walking (7.1)	Walking (6.5)

4. Methods

4.1. Two-step floating catchment area (2SFCA) method

The 2SFCA is the most developed and commonly employed method for measuring healthcare accessibility (Cheng et al., 2012; Neutens, 2015; Luo and Wang, 2003). It defines the service area of a healthcare provider by a threshold while accounting for the availability of the provider by its surrounded demands. The calculation process comprises two steps. The first step is to calculate the service coverage of hospitals. For each hospital at location j, all population points k which are within a distance d_0 from location j are searched, and the area within the threshold d_0 is set as the catchment area, then the physician-to-population ratio R_j within the catchment area is computed:

$$R_j = \frac{P_j}{\sum_{k\in\{d_{jk}\leq d_0\}} D_k} \tag{1}$$

where P_j is the number of physicians of hospital at location j, representing supply capacity; D_k is the size of elderly population of sub-district k whose centroid[4] is in the catchment area (i.e. $d_{jk} \leq d_0$), representing the quantity of demand; d_{jk} is the distance between j and k.

The second step is to sum up the service of each population point received from hospitals. For population point i, all hospitals that fall within the distance d_0 from point i are searched, and then sum up the R_j – obtained in the first step – of which hospital location falls within the catchment area centred at i (i.e. $d_{ij} \leq d_0$) as accessibility A_i:

$$A_i = \sum_{j\in\{d_{ij}\leq d_0\}} R_j \tag{2}$$

where A_i is the accessibility to hospitals at population point i; d_{ij} is the distance between i and j. A larger value of A_i represents a higher level of accessibility. The first step of 2SFCA method measures the availability of hospital resources at supply location, and the second step sums up the ratios in the overlapped service areas to calculate accessibility at a demand location (population point). As a result, the 2SFCA method takes into account the interaction between demand and supply, and measures accessibility across administrative borders, which reflects health-seeking behaviour in the real world.

Figure 3 shows a simple example to illustrate the 2SFCA method. Consider a study area consisting of 15 zones, 15 residents, and 2 hospitals (one physician per hospital). In this example, the catchment area of hospital H1 has one physician and six residents, and therefore carries a ratio R_{H1} as 1/6. In the same way, the ratio R_{H2} is 1/7. A resident in zone 6 lives in an area overlapped by catchment areas of H1 and H2, and has access to both hospitals (Figure 3b), and thus enjoys a higher level of accessibility, $A_6 = 13/42$ (1/6+1/7). The second step identifies the overlapped area which shows that hospitals H1 and H2 are both within the catchment area of the resident in zone 6. It is noted that the catchment area in the first step is centred at hospital location so that the travel distance between the hospital and any resident within the

[4] Due to the unavailability of population data at a lower-level division (e.g. residential community), population-weighted centroid of sub-district is unable to be calculated. However, we use the office address of sub-district as a proxy for the population-weighted centroid, given that most sub-district offices in Nanjing locate in the population-clustered place within its administrative area.

catchment area does not exceed the distance threshold. In the second step the catchment area is centred at a population point, and it is assumed that residents only visit hospitals within the catchment area.

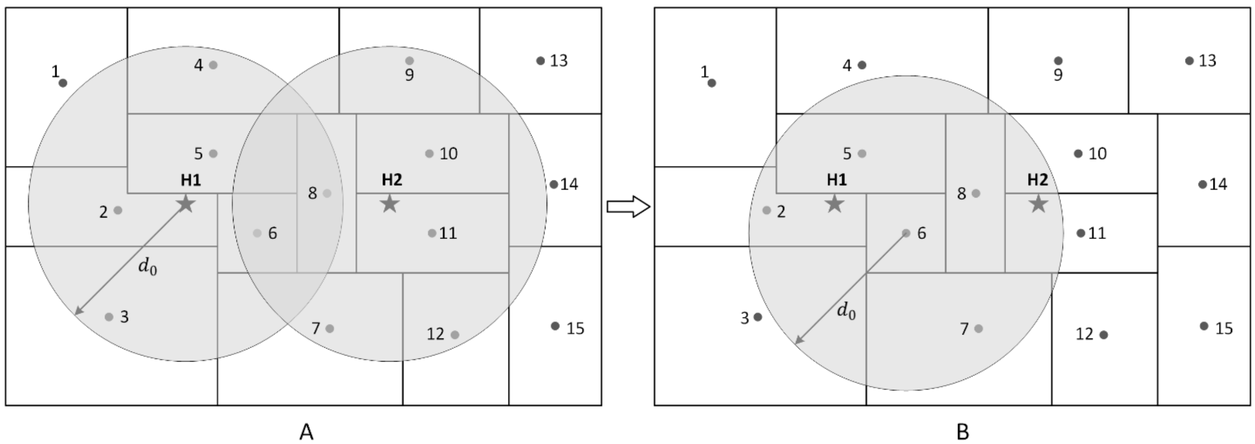

Figure 3. The two-step floating catchment area (2SFCA) method (A = first step, B = second step, adapted from Neutens (2015))

In our study, the distance between population point and hospital is measured by the network distance. This is the length of the shortest path from trip origin to destination along the street network. A distance threshold, rather than a travel time threshold, is employed for accessibility calculation because travel time varies greatly depending on modes of travel. Also, travel time fluctuates throughout the day. Note that the main debate of the 2SFCA method relates to what is the reasonable catchment size of healthcare services and what is the suitable function to address the distance decay effects. Instead of a subjectively pre-assumed threshold, we employ the revealed travel distances of elderly's medical trips. The median travel distance of elderly's hospital visits (Table 1) is used as the reference for a reasonable catchment size – primary ($d_0 = 2.3\ km$), secondary ($d_0 = 4.8\ km$), and tertiary ($d_0 = 10.4\ km$) – and reflects travel demands under the current distribution of healthcare services in Nanjing. We also think the median distance is more useful to indicate the (un)ease to reach hospitals, not skewed by extremely high or low values (different from the average distance). On the other hand, the limited number of observations (i.e. medical trips shown in Table 1) – particularly primary and secondary hospital visits – causes difficulties in accurately calibrating the negative exponential or other complicated functions. We thus employ the rectangular function to capture distance decay behaviours in hospital visits. That is to say a hospital is equally accessible by older adults within the catchment area and equally inaccessible out of that area.

4.2. Accessibility Gini coefficient

In addition to measuring the level of spatial access, this study investigates equity in accessibility of hospital services within administrative districts by applying the Gini coefficient. This indicator – representing the overall degree of inequity – is thought to be of good interpretability and easily explainable to policymakers (Guzman et al., 2017; Lucas et al., 2016; Witlox, 2017). It was first developed to measure wealth or income inequality by revealing the income distribution of a nation's population (Ceriani and Verme, 2012), and often applied to show relative deprivation in a society (Waters, 2000). The Gini coefficient ranges from zero (indicating a completely equitable distribution of accessibility) to one (indicating a completely unequal distribution). In this study, the index is a measure of statistical dispersion which reflects the inequality in the distribution of accessibility. In order to provide a practical guide for policymaking, we calculate the accessibility Gini coefficient for each administrative district given that it is basically the main body carrying out health infrastructure investments. The Gini coefficient of the ith administrative district G_i for showing equity in accessibility to hospitals is calculated by:

$$G_i = \frac{1}{2N^2\overline{A_i}} \sum_{m=1}^{N} \sum_{n=1}^{N} |A_{im} - A_{in}| \tag{3}$$

where A_{im} and A_{in} correspond the level of accessibility for sub-district m and n in district i; $\overline{A_i}$ is the average level of accessibility over all sub-districts in district i; and N is the total number of sub-districts.

5. Results

5.1. Accessibility to hospital services

In this section, geographical accessibility to multi-tier hospital services for elderly population is presented. Figure 4 displays how the spatial pattern of accessibility is different, with primary hospitals more accessible in the suburbs (e.g. Qixia and Gaochun) while tertiary hospitals having better accessibility in areas surrounding the CBD (e.g. Qinhuai and Xuanwu). The level of accessibility to tertiary hospitals is quite unevenly distributed, decreasing significantly from the city centre outwards, due to the concentration of tertiary hospitals in central areas (Figure 2). The coefficient of variation – the ratio of the standard deviation to the mean – reaches 0.69, which reflects the unfavourable inter-district disparities. However, the situation is not the same for the accessibility to primary and secondary hospitals where high accessibility levels are not so pronounced in the city centre. Primary and secondary hospitals are more accessible in wider areas, evidenced by the overall smaller coefficients of variation (0.60 and 0.49 respectively) and several highly reachable patches on the outskirts. This general picture about accessibility reflects the locational patterns of multi-tier hospitals with tertiary hospitals centralised and secondary and primary hospitals more dispersed across the city.

Figure 4 shows that the spatial variations in accessibility among multi-tier hospitals are different. For tertiary hospitals, 18 out of 25 are located in the urban districts, i.e. highly centralised distribution improving the level of accessibility in this region. For instance, on average, every thousand older residents in Qinhuai District tend to access 29 physicians, almost 15 times of people in Pukou District accessing only two physicians. In case of access to secondary hospitals, the equilibrium of accessibility distribution is relatively better. People in the northern part – Liuhe District – experience the lowest level of secondary hospital access, with four physicians per thousand residents. In addition, 15 out of 19 sub-districts in Liuhe District have no access to secondary hospitals (zero-level accessibility). Geographical accessibility to primary hospitals is relatively smoothly distributed, without spiking peaks. It should be noted that the Qixia District – a suburban district – enjoys the highest level of overall accessibility to primary hospitals (three physicians per thousand persons). The five urban districts, however, provide insufficient primary care services for older people (roughly one physician per thousand persons).

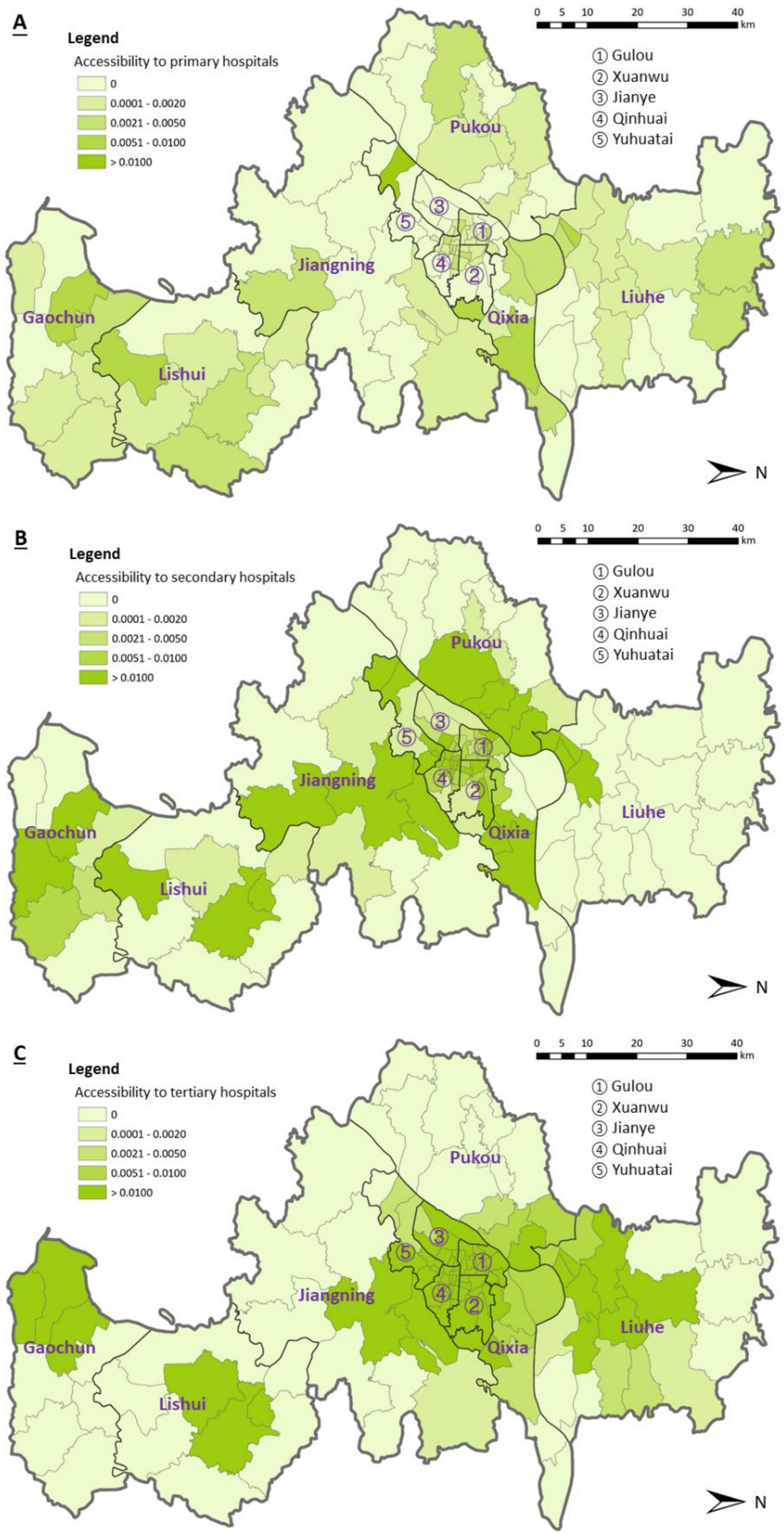

Figure 4. Geographical accessibility to multi-tier hospitals (A = primary, B = secondary, C = tertiary)

Drawing on these results, Figure 5 identifies the overlapped multi-tier hospital access zones. Three categories are made: lacking service zone (no hospital services provided), effective service zone (at least one tier of hospital services provided), and core service zone (all tiers of hospital services provided). The core service zone surrounds the CBD and is scattered in the suburban districts. The effective service zone covers all urban districts and most parts of suburban districts. The lacking service zone is widely distributed and dispersed in peripheral areas, such as the southwestern region. This result corroborates earlier studies on the unfavourable condition for suburbanites in accessing healthcare services (McGrail and Humphreys, 2014; Shah et al., 2017). These hospital care shortage sub-districts are hotspot areas – red-coloured zone in Figure 5 – with priorities for policy interventions.

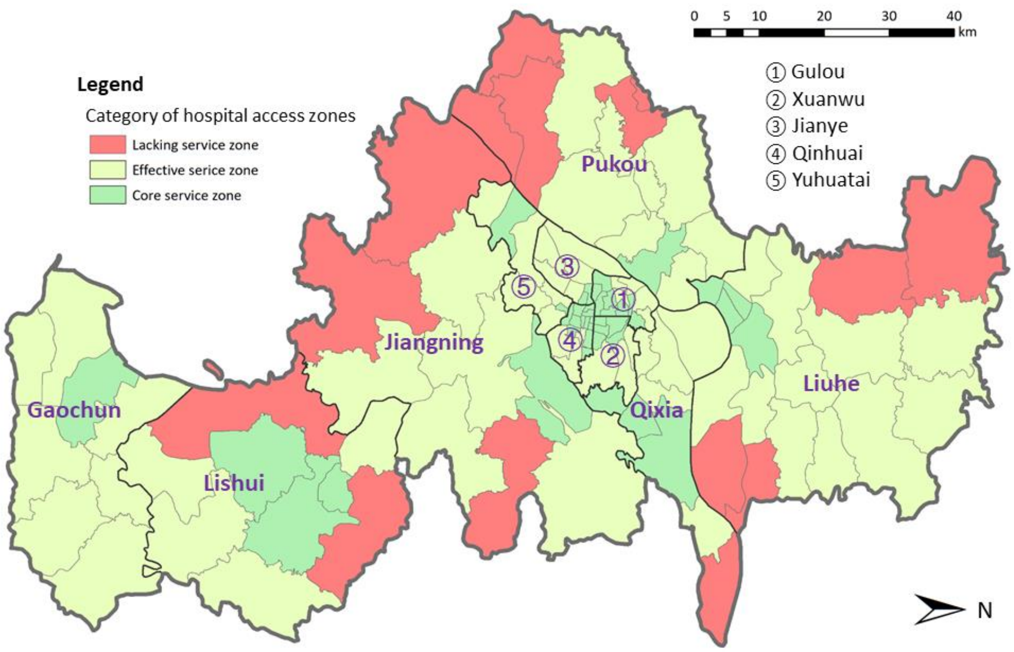

Figure 5. Category of multi-tier hospital access zones

5.2. Equity in accessibility

The use of Gini coefficients to analyse equity in accessibility has an added value in cases with significant concentrations of hospital services and spatial segregation of elderly population. It helps us to understand the impacts of differences in hospital service supply and population demand on the distribution of accessibility. Figure 6 presents the equity in accessibility to multi-tier hospitals within administrative districts, where X-axis is the (min-max) normalised average level of accessibility and Y-axis shows the accessibility Gini coefficient. A min-max normalisation does not change the shape of the distribution of the raw data. It is expressed as $x' = \frac{x - \min(x)}{\max(x) - \min(x)}$, where x is the original value of accessibility, x' is the normalised value. A district point close to the lower-right indicates a favourable circumstance, namely a higher level of overall accessibility and access being fairly distributed among elderly population. We can see that Qixia, Gaochun, and Liushui – all suburban districts – appear to have a good performance pertaining to accessing primary hospital services. On the other hand, Qinhuai, Xuanwu, Gulou, and Jianye – all urban districts – provide adequate and equal tertiary hospital services. In regard to secondary hospitals, although Yuhuatai District provides the most accessible services, the fairness in the distribution of accessibility is not satisfactory.

Figure 6. Equity in accessibility to multi-tier hospitals (A = primary, B = secondary, C = tertiary)

Imbalance and inequality of geographical accessibility to hospitals are present within 11 districts (i.e. intra-district disparity). Primary hospitals in Yuhuatai and Jiangning Districts tend to be most unevenly distributed, with accessibility Gini coefficients 0.94 and 0.74 respectively. Accessibility inequality for secondary hospitals remains high in Liuhe and Qixia Districts. In terms of tertiary hospitals, Pukou District ranks the first on the injustice of accessibility distribution (Gini coefficient = 0.83). When looking at multi-tier hospitals overall, Jiangning District shows fairly undesirable results: poor access to all tiers of hospitals and low level of equity (near the upper-left corner in Figures 6a, 6b and 6c). This implies that older people in Jiangning District have insufficient hospital services whilst experiencing greater unfair and unbalanced services compared to their counterparts in other districts.

6. Discussion and conclusion

The 'long-life society' in China makes it increasingly important to rationally allocate hospital care resources. As a basic prerequisite, we need to understand the distributional pattern of hospital service supply and demand among elderly population. However, there is a lack of empirical scientific analysis to examine the spatial access to multi-tier hospital services specific to Chinese elderly people. This study tried to fill this gap by measuring geographical accessibility to hospitals in Nanjing, identifying spatial variations within and across administrative districts. Results reveal the spatial characteristics of hospital distribution and the unbalanced pattern of hospital access, enriching research on the equity of healthcare and providing a reference for knowledge-based health planning and interventions.

In this study, we measured accessibility at the sub-district level applying the two-step floating catchment area method. The travel pattern of elderly's medical trips was analysed to determine the reasonable catchment size. Since hospitals are spatially dispersed and travel patterns reaching different tier of services vary, the differences in the level of accessibility among districts – the inter-district disparity – are obvious. In general, upper-tier hospitals are allocated more unevenly than the lower-tiers. More specifically, a remarkable concentration of tertiary hospitals is detected: spatial agglomeration in the city centre and several prominent peripheral sub-districts. Accessible sub-districts concerning secondary hospitals are mainly spread over the southern part of the city while primary hospitals appear to be more reachable in the suburban districts. Combining the multi-tier hospital services overall, lacking service zones – without any tier of hospitals – are identified on the outskirts and these areas are thus in great need for the allocation of hospital facilities. In addition, the intra-district inequity in accessibility is evaluated to identify areas which are better-off or worse-off. It is found that elderly people are better-off in Qinhuai District, with a relatively high level of fairness to access primary, secondary, and tertiary hospitals. Nevertheless, elderly people in Jiangning District experience less equitable access to the overall hospital services. When looking at each tier of hospitals separately, Yuhuatai District witnesses the most unequal distribution with regard to primary hospitals, Liuhe District appears to unbalance secondary hospitals, and Pukou District has the highest disparity in accessing tertiary hospitals.

These findings are relevant for policymakers in terms of future investment prioritisation in order to reduce disparities in health developments. The unequal situation can be tackled via localised interventions and integrated spatial planning strategies. Essentially, in order to enable a reduction of inter-district unbalanced situation, primary hospitals should be effectively deployed in the city centre and upper-tier hospitals are allocated to suburban areas. More importantly, healthcare resources can be optimised and coordinated across administrative districts at the boundaries of closely settled hospital under-served areas. In regard to addressing the intra-district disparity, tailor-made interventions could be made in specific districts, depending on local actual situations. If a district has a high level of overall accessibility but access being unevenly distributed (e.g. Yuhuatai District), we may relocate current hospitals within this district to enable balanced developments and fully exploit existing healthcare resources. If the access is both inadequate and unequal (e.g. in Liuhe District), more hospitals should be deployed by means of building new hospitals or branches, or expanding the service capacity of existing hospitals. In addition, inter- and intra-district healthcare equity should be considered in a coordinated manner in order to find out the optimal layout of health facilities. Although a focus on investing in certain districts may mitigate intra-district disparities, it will cause higher chances of inter-district inequalities. For elderly inhabitants in big cities, improving intra-district equality seems to be of high importance. It will reduce their difficulties in crossing districts – long distances travelled – to seek healthcare services.

Our results reiterate that spatial distribution of hospitals determines to a great extent the level of geographical accessibility (Agbenyo et al., 2017; Yin et al., 2018), and offer practical significance to strategically advance the hierarchical healthcare systems in China from a geographical perspective. It is actually a common phenomenon that many other Chinese cities – similar to Nanjing – are experiencing unbalanced developments of multi-tier hospitals services, typically tertiary hospitals concentrated in the city centre and primary hospitals more allocated in the suburbs. In order to reinforce the two-directional referral network, urban areas in a city should prioritise lower-tier hospitals while suburban areas make more investments in upper-tier hospitals.

Based on our results, some future research directions can be envisaged. First, our data come from a conventional household travel survey, which may under-report medical trips. Intercepts surveys that are conducted in hospitals could provide more useful information estimating people's medical travel pattern. In addition, since healthcare services are not exclusive for elderly people, future studies should consider the competition effects between the elderly and the non-elderly using advanced methods, e.g. a multi-mode and variable-demand 2SFCA model (Tao and Cheng, 2019). Second, access to healthcare is multidimensional, and this study only focuses on spatial factors (i.e. geographical accessibility). Non-spatial factors, such as gender, income, religion, employment, and social status, which may have important influences on individuals' access to hospitals (Guagliardo, 2004) are not considered. Non-spatial barriers may be alleviated through policy interventions, e.g. a health insurance system with good coverage, and health resources towards socially disadvantaged and minority groups. Third, this study adopted the rectangular function – a dichotomous measure – for the two-step floating catchment area method to calculate accessibility. A negative exponential function, better capturing distance decay effects, should be calibrated and used for future investigations if more healthcare utilisation data are available. Fourth, caution is warranted in interpreting the accessibility Gini index due to its inherent limitation that the same Gini coefficient but with different accessibility distributions. Alternative measures, e.g. the Theil index and the entropy index, could be used in future studies. Despite these limitations, this study provides a realistic appraisal of elderly's spatial access to hospital care services, taking as the essential first step towards optimising the spatial distribution of multi-tier hospitals in a Chinese context.

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