Spatial accessibility to emergency care in Sichuan province in China

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Abstract

Timely access to emergency care, which still remains insufficient in China, can substantially improve overall health outcomes. A better understanding of emergency care from the perspective of spatial accessibility is essential for future healthcare planning. This study provides a brief introduction to the emergency medical service system of China assessing the spatial accessibility of emergency care and associated social-economic characteristics in Sichuan province. Based on demographic and hospital administrative data in 2018, we measured the spatial accessibility employing the nearest-neighbour method and identified associated social-economic factors by the conventional Ordinary Least Square (OLS) approach. Travel time analysis revealed a relatively high level of overall spatial accessibility to emergency care in Sichuan. However, substantial geographical disparity in accessibility could nevertheless be observed throughout the province, with the eastern area presenting much better accessibility than the western area. Regression results suggested that county-level discrepancies with respect to accessibility could be significantly attributed to variance in local economic development, urbanization level and administrative area. These findings indicate that long-term efforts need to be made by the central government in China optimizing allocation of healthcare resources, as well as fortifying financial support and providing preferential policies for economically disadvantaged regions.

Introduction

As a fundamental part of public health resource, emergency care refers to the health system capacity required to ensure effective, efficient provision of curative services for emergent health events (Calvello *et al.,* 2013). These events include a diverse set of acute conditions which should normally be treated at high-level healthcare facilities, with trauma, obstetric and surgical conditions being the most common examples. Without timely emergency care, patients would possibly face a poor prognosis and even death (Bhutta *et al.,* 2014; Gauss *et al.,* 2019; Tansley *et al.,* 2019). In fact, emergent conditions have become major contributors to mortality and disability rates in low and middle-income countries (Lopez and Murray, 1998; Norton and Kobusingye, 2013), where the paucity of emergency care resources remains a crucial problem. The improvement of accessibility, availability and quality of timely emergency care has long been addressed and advocated throughout a worldwide range. In 2007, the World Health Assembly (WHA) proposed Resolution 60.22, which addresses the lack of emergency care as a worldwide healthcare issue, especially in rural and urban communities of low and middle-income countries (WHA, 2007). According to a proposal advocated in 2015 (Meara *et al.,* 2015), a minimum of 80% coverage of emergency surgical and anaesthesia services per country should be guaranteed in order to achieve universal access to essential medical services.

To understand the provision of emergency care, an accurate assessment of current resources and a detailed knowledge of populations' access to these resources are required. Access to healthcare can be evaluated in various ways (Guagliardo, 2004), with spatial accessibility being recognized as an important component in the evaluation of a population's overall access to healthcare (Berke and Shi, 2009). Since the time needed to reach medical care is considered a key performance indicator of emergency care, distance to the nearest provider has been widely adopted in measuring spatial accessibility to emergency care. Other measuring methods, such as the provider-to-population ratio and gravity

models, are used less often in this field of research. Although assessments of spatial accessibility to emergency care have been carried out in several countries (Tansley *et al.,* 2015; Juran *et al.,* 2018; Khubchandani *et al.,* 2018; Ouma *et al.,* 2018; Nishikawa *et al.,* 2019), most studies focused on the poor spatial accessibility resulting from regional resource scarcity, with less attention paid to inter- and intra-regional inequities. It is therefore noteworthy that Universal Health Coverage (UHC), one of the fundamental goals of regional equity, should receive equal attention in the evaluation process.

China, the largest developing country in the world, provides an example of a country facing challenges of uneven distributions of healthcare resources (including emergency healthcare resources). This situation is of high public concern in China and has become one of the major tasks for healthcare reform. Although the healthcare system has been improved substantially since the initiation of a new round of national health system reform in 2009, distinctive regional disparities in healthcare resources, especially those tackling certain medical conditions, still remain neglected (Shen *et al.,* 2014; Liu *et al.,* 2015; Pan *et al.,.* 2016; Zhang *et al.,* 2017; Wu, 2018). Meanwhile, inadequate studies have been conducted for evaluating access to emergency care in China. A better understanding of emergency care from the perspective of spatial accessibility is therefore desperately needed in order to provide suggestions for future policymaking.

In this study, we first provide a brief introduction to China's emergency medical service system using Sichuan Province as an example calculating the spatial accessibility to emergency care as reflected by the time needed for getting to the nearest healthcare provider available. We further aimed to explore social-economic determinants to spatial accessibility at the county level as the findings were expected to depict the emergency healthcare accessibil-

ity as well as providing evidence-based implications for future policymaking and medical resource allocation.

Emergency medical service system in China

The embryo of China's emergency healthcare system dates back to the 1950s, with its rapid development evident from the list of *opinions on strengthening urban emergency care* announced by the Chinese Ministry of Health (1980). Such development brought about progressive establishment of first-aid stations (sub-stations) in urban regions in order to provide field first-aid and patient transfer services, while the *Medical Institution Management Regulations* was issued in the next decade by the Chinese Ministry of Health (1994), which made it mandatory for hospitals to set up emergency rooms or emergency departments according to their levels. Currently, the entire procedure of emergency care in China covers both pre-hospital and in-hospital emergency care, which reflects the remarkable improvement of China's emergency healthcare system over the past decades.

The providers of emergency care in China can be classified into three categories: emergency centres, hospitals and primary healthcare institutions with 24-hour emergency medical services (Figure 1). City hospitals and community health centres (CHCs) constitute the urban emergency healthcare system, while the rural part comprises county hospitals and township health centres (THCs).

The basic responsibility of an emergency centre is to provide management services such as ambulance dispatching and telephone advice. However, in order to conform to regional characteristics in China, different development strategies have been applied by local governments, bringing about various types of emergency centres. Depending on their responsibilities, emergency centres can be classified into four classes: i) The command type, which
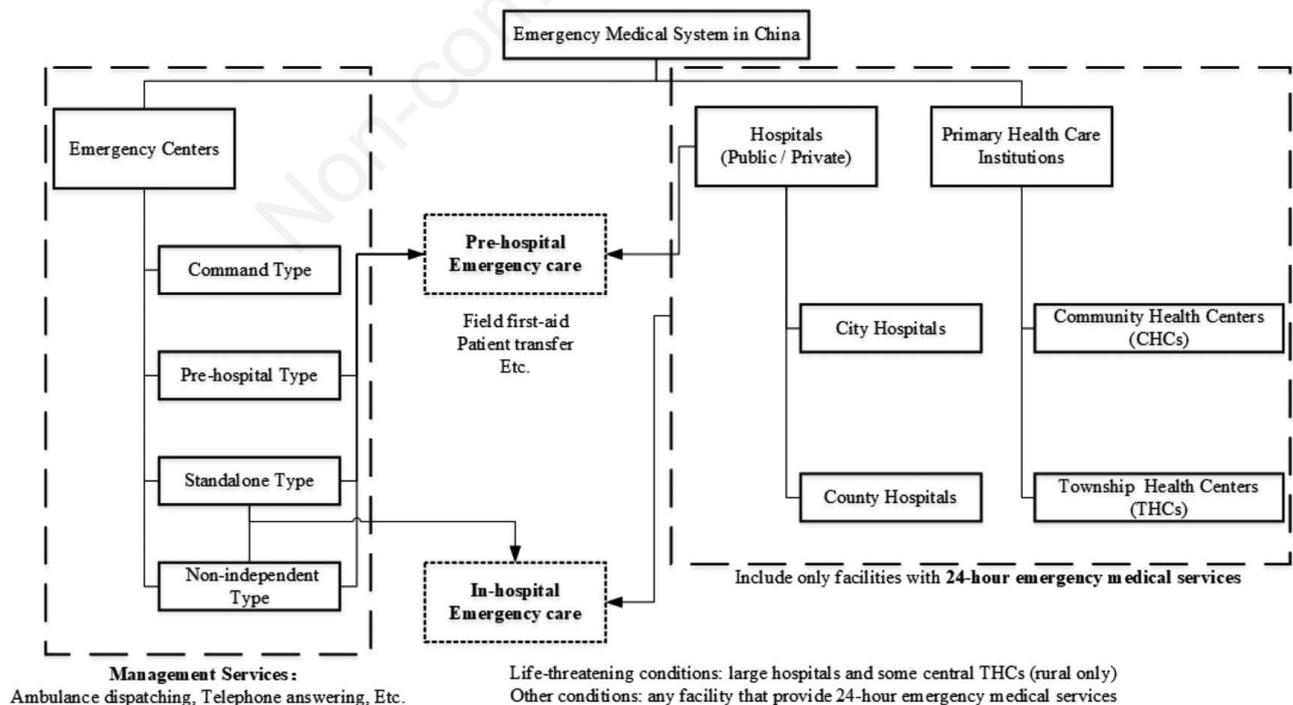

Figure 1. Emergency medical service system in China.

only provides management services; ii) the pre-hospital type, which provides field first-aid and patient transfer services in addition to management services; iii) the stand-alone type, which is capable of in-hospital resuscitation apart from the list of services provided by the pre-hospital type; iv) the non-independent type, which is part of a large hospital and provides the same functions as the stand-alone type.

Hospitals and primary healthcare institutions are mainly responsible for in-hospital emergency care. Qualified hospitals, which are evaluated and certified by local governments or authorized emergency centres, can also participate in pre-hospital emergency care. For cities with command-type emergency centres, these hospitals are usually in charge of the entire pre-hospital emergency service under the order of emergency centres. Depending on the severity of patient conditions, in-hospital emergency care can be provided by facilities with different levels. Large hospitals and some central THCs in rural region are usually responsible for handling the most life-threatening conditions. Typically, healthcare at the level of Intensive Care Unit (ICU) is provided in these facilities. Other less life-threatening conditions can be handled by any healthcare facility that provides 24-hour emergency medical services, which mainly consist of general hospitals at different levels, such as CHCs and THCs. It is noteworthy that in remote areas where healthcare resource remains insufficient, central THCs play a pivotal role in providing in-hospital emergency care.

Materials and methods

Study area and data

Sichuan is an inland province located in south-western China between latitudes 92°21'~108°12'E and longitudes 26°03'~34°19'N. It's the fifth largest province (about 487,000 km^2) in China and also one of the most populated ons, with a population of 83.41 million in 2018 (National Bureau of Statistics of China, 2019). According to the divisions of administrative areas in Sichuan in 2018 (Ministry of Civil Affairs, 2018), there are 21 prefectures that includes 183 county-level administrative units. Geographically, there is a striking difference between the north-western and south-eastern parts of the province, which is approximately evenly divided by the Hengduan Mountains (Figure 2). The former is characterized by high plateaus and mountains, low population density, underdeveloped economy and road networks, while the prominent features of the latter is a flat and productive plain with high population density, well-developed economy and well-constructed road networks. Three minority autonomous regions (Aba, Ganzi and Liangshan), where ethnic minorities are densely populated, are located in the north-western part of the province.

The emergency healthcare facility data for 2018 was obtained from the Health Bureau of Sichuan Province, which included each facility's name, address, type of ownership (public, for-profit private and private not-for-profit) and organization (hospital, emergency medical centre, THCs/CHCs). As the first step, we screened the database and extracted facilities qualified as providers of emergency care according to a set of criteria. The inclusion criteria were as follows: facility covered by the emergency service network; visits to the emergency care unit larger than zero in preceding year; and number of hospital beds in the emergency department larger

than zero. Facilities were included on condition that they met one of the criteria listed above. All eligible facilities were considered as potential providers of emergency care in this study. After this step, we geocoded the locations of these facilities on Baidu Map using their names and addresses.

In order to measure the spatial accessibility to emergency care reflected by the time needed to the nearest emergency healthcare provider, we retrieved the road network data and administrative boundary data from the 1: 250,000-scale topographic database of the National Fundamental Geographic Information System of China, provided by the National Geomatics Center of China. According to road class, traffic, physical conditions and highway technical standards, a standard speed was used as limit for each section of the road used for calculating the travel time, *i.e.* 120 km/h for highways, 100 km/h for state roads, 80 km/h for provincial roads, 60 km/h for county roads and 40 km/h for village roads.

The population data in 2018 was obtained from the Sichuan Province Statistical Yearbook (Bureau of Sichuan, 2019). The data were annually reported by the Department of the Statistics Bureau of Sichuan, which included the county-level population in 183 counties. Considering the usefulness of a higher resolution of population data, we further applied the LandScan 2017 (Bhaduri *et al.,* 2002), which provides the finest available resolution of global population distribution data from the Oak Ridge National Laboratory in the U.S. (https://www.ornl.gov/), to convert the actual county-level population data into gridded data. Specifically, with a resolution of approximately 946 meters, the LandScan dataset was used to calculate the population ratio for each grid cell within counties through dividing the population of each grid cell by the total population of the county. Then we multiplied the actual population data from the Statistical Yearbook by the calculated population ratio to obtain this level of resolution.

Statistical approach

Assuming that residents only approached the nearest healthcare facility to seek healthcare, the nearest-neighbour method was employed to calculate the shortest time of travel for each residential location to the nearest emergency healthcare facility. The idea to present the actual healthcare utilization attitudes of the residents in an area in this way is quite simple and straightforward, which made it a widely adopted method for measuring the spatial accessibility to health facilities. However, the method is not without limitations as has been pointed out by Pan *et al.,* 2015, *e.g.*, the assumption to take residents' preference towards healthcare institutions into consideration is rigid, and the analytical procedure fails to take the capacity of suppliers and the amount of demand into account. However, considering that the time travel was the only key factor affecting residents' choice in the process of seeking emergency care, we felt this method reasonable and adopted it to depict the spatial accessibility to emergency care. Specifically, the shortest approach to a healthcare facility equalled the summed length of travel time by a motorized vehicle and walk needed to reach the nearest available vehicle. The speed limits for the different road sections were set as described above and the speed walking was set as 5km/h. To detail spatial variations of the shortest time of travel, we classified the time cost into 12 categories ranging from 0-5 minutes up to >60 minutes.

In addition, we calculated the weighted average travel time based on the population data for the entire Sichuan Province, including its 21 prefectures and 183 counties. Considering that the distribution of travel time tended to be skewed, we used median

and inter-quantile range (IQR) to reveal the central tendency of its variation. To compare our outcomes with international recommendations that more than 80% of the population should be able to receive emergency medical services within two hours, we derived the specific time of travel when the covered population reached 80%. Inversely, to reflect the regional disparities in spatial accessibility we also presented the proportion of the population covered based on different travel time intervals. Moreover, to reflect the specific context of healthcare facility distribution in Sichuan, we compared differences in the shortest travel time between various settings including all facilities but excluding private as well as private not-for-profit facilities (both for-profit and not-for-profit).

To examine the relationships between social-economical characteristics and spatial accessibility to the nearest emergency healthcare

facility at the county level, we utilized the conventional, Ordinary Least Square (OLS) method. The outcome variable was the median of the shortest travel time of each county. Due to the risk of travel time being skewed at the county level, we employed the natural logarithm of this figure to fulfil the assumption of linearity, as the result the model coefficients could be used to measure the proportional change in the shortest travel time. A list of social-economic indicators was also considered in this study, namely the population (per 10,000), the area (per 1,000 km^2), the gross domestic product (GDP) per capita (1,000 Yuan) and the urbanization rate (percentage of urban population). Based on previous literature and our prior knowledge (Wang *et al.,* 2018), counties with more densely distributed populations were often associated with a higher level of economic development and urbanization with better accessibility to emergency care. Therefore,
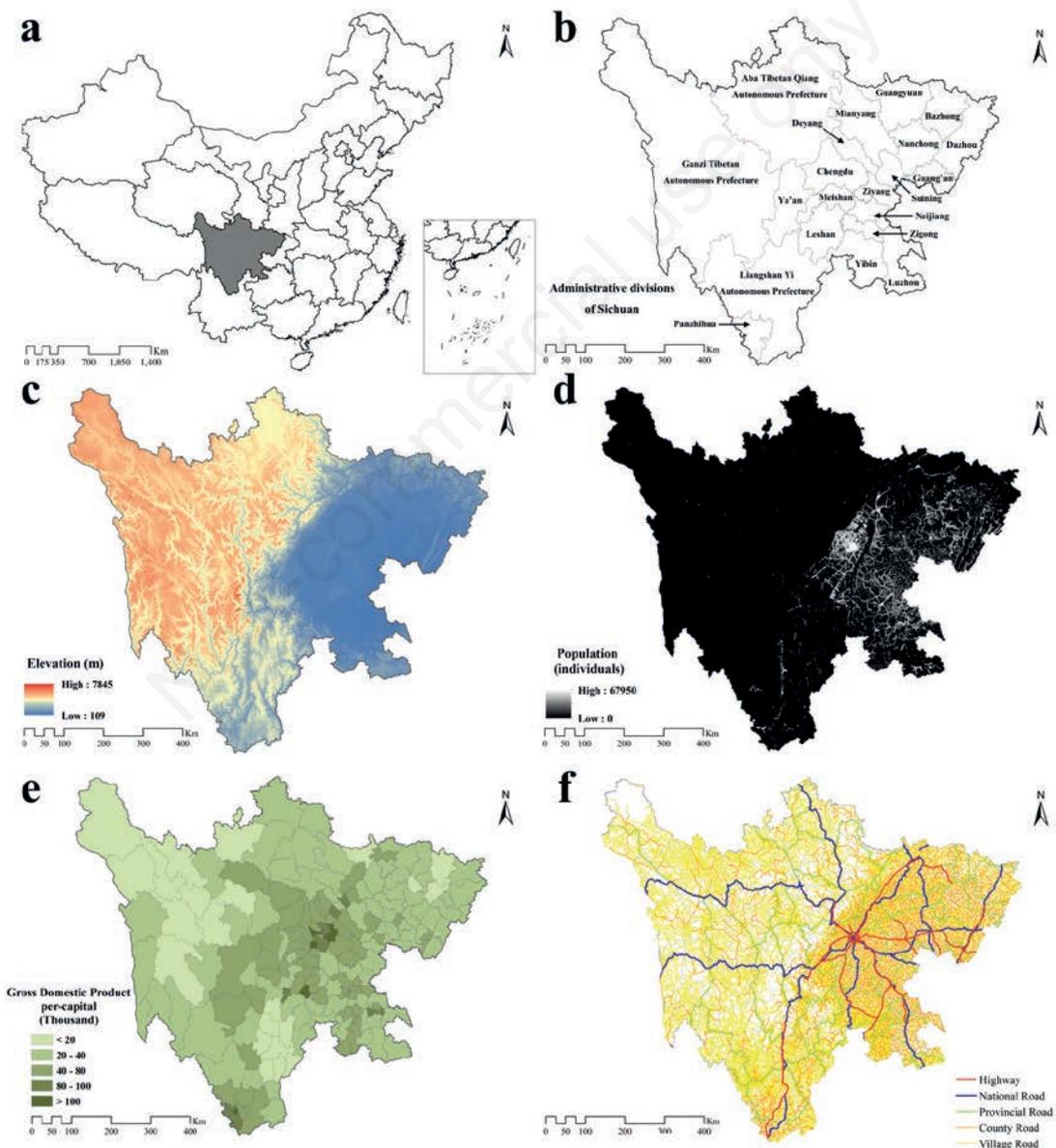

Figure 2. Position, administrative division, elevation, population density, GDP, and transportation of Sichuan province, China, 2018.

we hypothesized that population size, GDP per capita and urbanization rate had a negative association with travel time to the nearest emergency care facility. We also considered that counties with a larger administrative area tended to have a lower accessibility to emergency care. Before performing linear regression, we tested the collinearity of all included independent variables with Variance Inflation Factor (VIF). Generally, variables with a VIF <5 were acceptable, while it was problematic to include one with a VIF >10 in the regression model leading towards "severe collinearity" with unstable parameter estimates, inflated standard errors on estimates and consequently biased inference statistics (Dormann *et al.*, 2013). A two-side *P*-value was used with set to 0.05 to determine statistical significance. The neatest-neighbour method was performed by ArcGIS, v. 10.5 (ESRI, Redlands, CA, USA) and descriptive analysis and regression analysis conducted by SAS, v. 9.4 (https://www.sas.com/en_us/software/sas9.html). To improve the data accessibility and reproducibility of our analysis for policy makers and researchers, we uploaded some of the inputs including population data and road network data in the Zenodo, a general-purpose open-access repository developed under the European OpenAIRE programme. Other inputs such as the administrative data of healthcare facilities can be accessed from the Health Commission of Sichuan Province.

Results

Description of emergency healthcare facility

In 2018, there was a total of 8,012 health facilities in Sichuan Province, 2,576 hospitals, 5,418 THCs/CHCs and 18 emergency centres. After screening for potential eligibility of these facilities based on the pre-defined inclusion criteria, we extracted 5,031 emergency healthcare facilities, including 1,757 hospitals and 3,271 THCs/CHCs as well as 3 emergency medical centres (Table 1). Nearly 80% of the them had public ownership and only 13.1% were for-profit private ones, while there were no not-for-profit ones. Compared to urban areas, a larger amount of emergency facilities (57.4%) were situated in rural areas with sparse populations in relatively vast territories. The results also showed that hospitals were more densely located in urban areas, with a large amount of THCs/CHCs located in rural areas.

Large regional disparity in emergency facility distribution was also found in this study across 21 prefectures. Chengdu, the capital city in Sichuan, had the highest amount of emergency facilities (654), which was 10 times more than that in Panzhihua, a city at the prefecture level with a population of 1.5 million. As seen in Figure 3, most of emergency healthcare facilities are clustered in eastern Sichuan, whereas the western regions, especially Ganzi and Aba, have a much lower distribution of emergency resource.

Table 1. Distribution of emergency healthcare facility in Sichuan province.

| | Area (km²) | Population (thousand) | Facility number (%) | Organization type | | | Public | Ownership | | |
				Hospital	THC*/CHC**	Emergency medical centre		Public	Private not-for-profit	Private for-profit
Total	486954	83410	5031 (100)	1757 (34.92)	3271 (65.02)	3 (0.06)	3972 (78.95)	399 (7.93)	660 (13.12)
Area									
Urban	34,753.76	43615	2142 (42.58)	1003 (46.83)	1137 (53.08)	2 (0.09)	1525 (71.2)	222 (10.36)	395 (18.44)
Rural	452200.24	39795	2889 (57.42)	754 (26.1)	2134 (73.87)	1 (0.03)	2447 (84.7)	177 (6.13)	265 (9.17)
Prefecture									
Chengdu	14326.61	16330	654 (13)	387 (59.17)	267 (40.83)	0 (0)	397 (60.7)	78 (11.93)	179 (27.37)
Nanchong	12476.22	6440	502 (9.98)	141 (28.09)	361 (71.91)	0 (0)	399 (79.48)	31 (6.18)	72 (14.34)
Dazhou	16600.55	5720	363 (7.22)	88 (24.24)	275 (75.76)	0 (0)	300 (82.64)	7 (1.93)	56 (15.43)
Mianyang	20242.56	4857	361 (7.18)	98 (27.15)	263 (72.85)	0 (0)	313 (86.7)	31 (8.59)	17 (4.71)
Liangshan	60353.06	4908	314 (6.24)	89 (28.34)	224 (71.34)	1 (0.32)	273 (86.94)	0 (0)	41 (13.06)
Bazhong	12296.61	3322	299 (5.94)	70 (23.41)	228 (76.25)	1 (0.33)	249 (83.28)	42 (14.05)	8 (2.68)
Guangyuan	16307.73	2667	296 (5.88)	67 (22.64)	229 (77.36)	0 (0)	264 (89.19)	23 (7.77)	9 (3.04)
Yibin	13249.51	4556	236 (4.69)	101 (42.8)	135 (57.2)	0 (0)	172 (72.88)	12 (5.08)	52 (22.03)
Leshan	12718.36	3267	230 (4.57)	84 (36.52)	146 (63.48)	0 (0)	185 (80.43)	29 (12.61)	16 (6.96)
Luzhou	12225.39	4324	213 (4.23)	105 (49.3)	108 (50.7)	0 (0)	131 (61.5)	22 (10.33)	60 (28.17)
Ganzi	150382.43	1196	187 (3.72)	43 (22.99)	144 (77.01)	0 (0)	187 (100)	0 (0)	0 (0)
Guangan	6339.98	3241	180 (3.58)	62 (34.44)	118 (65.56)	0 (0)	133 (73.89)	12 (6.67)	35 (19.44)
Aba	83107.97	944	179 (3.56)	32 (17.88)	147 (82.12)	0 (0)	174 (97.21)	2 (1.12)	3 (1.68)
Deyang	5906.97	3545	174 (3.46)	68 (39.08)	106 (60.92)	0 (0)	141 (81.03)	11 (6.32)	22 (12.64)
Suining	5318.76	3202	150 (2.98)	56 (37.33)	93 (62)	1 (0.67)	107 (71.33)	40 (26.67)	3 (2)
Meishan	7134.82	2984	144 (2.86)	64 (44.44)	80 (55.56)	0 (0)	101 (70.14)	34 (23.61)	9 (6.25)
Neijiang	5379	3699	136 (2.7)	54 (39.71)	82 (60.29)	0 (0)	102 (75)	8 (5.88)	26 (19.12)
Zigong	4378.25	2920	123 (2.44)	32 (26.02)	91 (73.98)	0 (0)	107 (86.99)	1 (0.81)	15 (12.2)
Ziyang	5740.86	2512	122 (2.42)	54 (44.26)	68 (55.74)	0 (0)	93 (76.23)	7 (5.74)	22 (18.03)
Yaan	15056.27	1540	104 (2.07)	33 (31.73)	71 (68.27)	0 (0)	90 (86.54)	9 (8.65)	5 (4.81)
Panzhihua	7412.74	1236	64 (1.27)	29 (45.31)	35 (54.69)	0 (0)	54 (84.38)	0 (0)	10 (15.63)

*Township health centre; **Community health centres.

The pattern of emergency facility distribution was relatively consistent with the variance in population density and economic development.

Shortest travel time to emergency healthcare facility

The result of the nearest-neighbour analysis showed that spatial accessibility to emergency healthcare facility is highly uneven throughout the province, with eastern Sichuan presenting higher level of accessibility than the western part (Figure 4). The shortest travel time to emergency facilities in eastern and south-eastern regions was found to be generally less than 15 minutes, while it exceeded 60 minutes in most areas of western and north-western Sichuan. It should be noted that the distribution of shortest travel time in western region is quite similar to the pattern of road networks, indicating that travel impedance is likely to be strongly associated with the road network constructions.

Overall, the median travel time to the nearest emergency facilities in Sichuan Province was found to be 6.9 minutes, with an IQR of 9.6 minutes (Table 2). The inference is that 80% of the
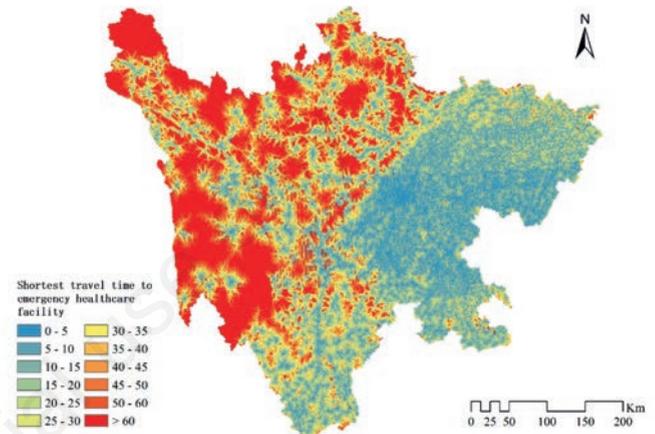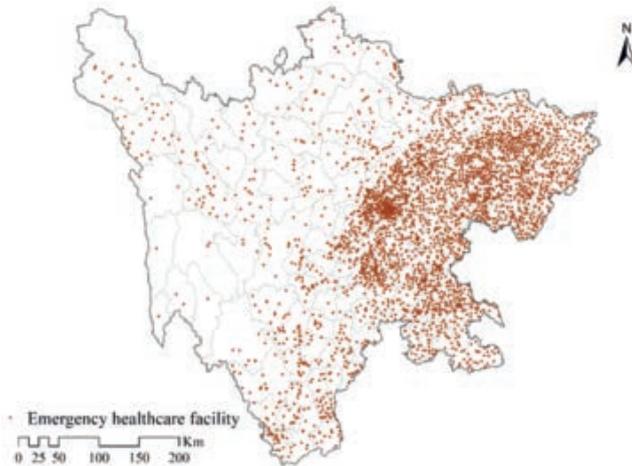

Figure 3. Distribution of emergency healthcare facility in Sichuan Province.

Figure 4. The shortest travel time to emergency healthcare facility in Sichuan Province.

Table 2. Distribution of shortest travel time in Sichuan province.

| | Shortest travel time (minute) | | | Percentage of covered population at different travel times | | | |
	Median (IQR*)	Mean (SD**)	80th percentile	(0,15)	(15,30)	(30,60)	(60, ~)
Total	6.89 (9.61)	9.57 (130.4)	14.57	81.05	15.8	2.51	0.64
Prefecture							
Chengdu	3.23 (5.71)	4.88 (151.47)	8.07	95.01	4.74	0.23	0.02
Zigong	5.46 (8.28)	7.27 (147.58)	12.07	86.92	12.41	0.67	0
Leshan	5.82 (8.84)	8.57 (131.58)	13.08	84.79	12.15	2.65	0.41
Guangan	6.04 (7.76)	7.77 (126.48)	12.09	87.16	11.92	0.92	0
Suining	6.12 (7.59)	7.86 (131.06)	12.28	87.06	12.44	0.49	0.01
Panzhihua	6.28 (8.89)	8.9 (90.52)	14.63	80.97	17.10	1.90	0.03
Deyang	6.36 (7.52)	7.84 (124.92)	12.23	87.80	11.74	0.44	0.02
Ziyang	6.86 (8.12)	8.52 (127.35)	13.07	85.11	13.48	1.41	0
Yaan	7.1 (10.27)	10.72 (116.08)	15.73	78.81	15.82	3.65	1.72
Meishan	7.13 (8.07)	8.59 (114.27)	13.12	85.04	14.18	0.76	0.02
Neijiang	7.19 (9.45)	9.18 (173.29)	14.83	80.42	17.73	1.85	0
Nanchong	7.28 (8.91)	8.87 (132.92)	14.04	82.49	16.39	1.12	0
Dazhou	7.45 (8.95)	9.07 (112.11)	14.18	82.38	16.34	1.26	0.02
Mianyang	8.06 (8.83)	9.67 (109.21)	14.62	81.05	17.38	1.25	0.32
Bazhong	9.86 (10.34)	11.71 (111.71)	17.81	71.35	25.90	2.72	0.03
Luzhou	9.86 (11.36)	11.76 (142.48)	18.34	70.11	26.18	3.58	0.13
Guangyuan	10.16 (11.07)	11.73 (93.3)	17.83	70.92	25.45	3.55	0.08
Yibin	10.88 (10.29)	12.22 (130.31)	18.06	69.26	27.64	3.08	0.02
Liangshan	10.91 (14.81)	14.94 (118.79)	22.43	62.42	26.66	9.14	1.78
Aba	20.81 (32.75)	28.69 (72.01)	48.53	39.42	23.87	23.98	12.73
Ganzi	28.86 (41.82)	41.25 (127.39)	61.1	29.90	21.63	27.72	20.75

*Interquartile range; **standard deviation.

population can access emergency services within less than 15 minutes (14.6), *i.e.* much lower than the international benchmark at 2 hours. Only 2.5% (2.09 million) of the population had to spend more than half an hour and only 0.6% (0.53 million) of the population needed to travel more than 60 minutes. Apart from that, Chengdu was found to have the best spatial accessibility (3.2 minutes), with Ganzi lagging far behind all the other prefectures in Sichuan (28.9 minutes). With the exception of Aba and Ganzi, over 60% of the population in all the other prefectures can access their nearest emergency facility within 15 minutes and more than 98% of the population would be able to be at nearest facility within 60 minutes. To better connect spatial accessibility to emergency care with the specific distribution of healthcare facilities in Sichuan, we compared the differences in shortest travel time between all facilities and those facilities after excluding all private facilities (for-profit and not-for-profit). In Table 3, an overall higher travel time after excluding the private facilities was noted, although the rise was insignificant, suggesting that the private facilities acted as supplement to the public facilities and were indeed able to help improve the spatial access to emergency care in the province. Accessibility in some prefectures, *e.g.*, Luzhou, Guangyuan, Yibin and Liangshan, were highly affected by the private facilities. We also found an increase in the shortest travel time by solely excluding the private facilities regardless if they operated for profit or not for profit. But the rise in the latter was larger than the former, which indicates that the for-profit facilities contributed more to accessibility than the not-for-profit private facilities. This pattern was also consistent with the distribution of other private facilities in Sichuan.

Geographical disparity in the distribution of shortest travel time

Despite a generally satisfying spatial accessibility to emergency facilities was found across the province, the uneven distribution of the shortest travel time at the prefecture and county levels cannot be ignored (Figure 5). For example, there was a difference of
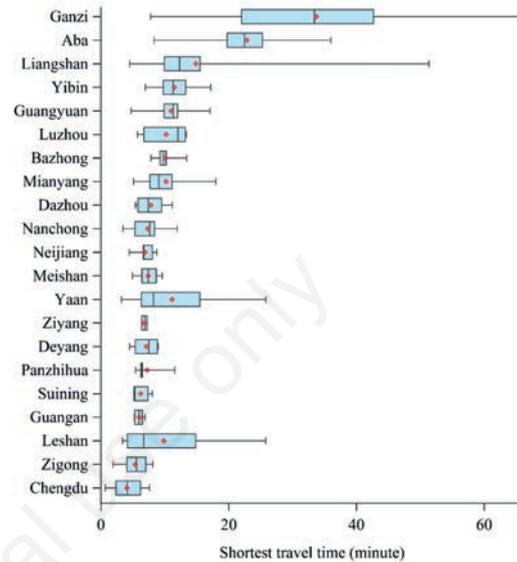

Figure 5. Distribution of shortest travel time to emergency healthcare facility within 21 prefectures in Sichuan Province.

Table 3. Differences in shortest travel time between various settings in Sichuan province.

	Shortest travel time (minute) / median (IQR*)						
	All facilities	Excluding private facilities	Change	Excluding private non-for-profit facilities	Change**	Excluding private for-profit facilities	Change**
Total	6.89 (9.61)	7.19 (9.75)	+0.30	7.01 (9.66)	+0.12	7.04 (9.75)	+0.15
Prefecture							
Chengdu	3.23 (5.71)	3.58 (5.84)	+0.35	3.34 (5.74)	+0.11	3.38 (5.78)	+0.15
Zigong	5.46 (8.28)	5.60 (8.17)	+0.14	5.54 (8.25)	+0.08	5.53 (8.13)	+0.07
Leshan	5.82 (8.84)	6.11 (8.72)	+0.29	6.08 (7.72)	+0.26	5.83 (8.81)	+0.01
Guangan	6.04 (7.76)	6.30 (9.12)	+0.26	6.08 (8.72)	+0.04	6.12 (7.59)	+0.08
Suining	6.12 (7.59)	6.32 (7.52)	+0.20	6.28 (8.86)	+0.16	6.30 (9.12)	+0.18
Panzhihua	6.28 (8.89)	6.46 (7.48)	+0.18	6.32 (7.51)	+0.04	6.43 (7.99)	+0.15
Deyang	6.36 (7.52)	6.50 (7.96)	+0.14	6.36 (7.52)	0	6.43 (7.48)	+0.07
Ziyang	6.86 (8.12)	6.89 (8.13)	+0.03	6.86 (8.12)	0	6.89 (8.13)	+0.03
Yaan	7.10 (10.27)	7.26 (10.40)	+0.16	7.21 (9.47)	+0.11	7.13 (10.27)	+0.03
Meishan	7.13 (8.07)	7.27 (9.48)	+0.14	7.24 (10.41)	+0.11	7.16 (8.10)	+0.03
Neijiang	7.19 (9.45)	7.49 (8.92)	+0.30	7.33 (8.99)	+0.14	7.22 (9.43)	+0.03
Nanchong	7.28 (8.91)	7.59 (8.41)	+0.31	7.39 (8.08)	+0.11	7.49 (8.93)	+0.21
Dazhou	7.45 (8.95)	7.62 (9.13)	+0.17	7.45 (8.95)	0	7.50 (9.10)	+0.05
Mianyang	8.06 (8.83)	8.24 (8.99)	+0.18	8.19 (9.00)	+0.13	8.09 (8.83)	+0.03
Bazhong	9.86 (10.34)	10.03 (10.33)	+0.17	9.98 (10.37)	+0.12	9.90 (10.35)	+0.04
Luzhou	9.86 (11.36)	10.38 (11.24)	+0.52	10.31 (11.36)	+0.45	10.16 (11.06)	+0.30
Guangyuan	10.16 (11.07)	10.86 (11.48)	+0.70	10.37 (11.26)	+0.21	10.37 (11.87)	+0.21
Yibin	10.88 (10.29)	11.48 (14.80)	+0.60	10.91 (14.81)	+0.03	11.43 (10.56)	+0.55
Liangshan	10.91 (14.81)	11.61 (10.36)	+0.70	11.06 (10.21)	+0.15	11.48 (14.80)	+0.57
Aba	20.81 (32.75)	20.83 (32.77)	+0.02	20.83 (32.76)	+0.02	20.82 (32.75)	+0.01
Ganzi	28.86 (41.82)	28.86 (41.82)	0	28.86 (41.82)	0	28.86 (41.82)	0

*Interquartile range; **compared to the median with that in all facilities (second column).

about 8 times (25.6 minutes) between the median travel times of Chengdu and Ganzi. There was also a notable disparity in the county-level travel time, which ranged from 0.7 minutes (Qingyang District) to 65.6 minutes (Batang County). It is noteworthy that Ganzi had the largest inequality in the county-level travel time with an IQR of 20.7 minutes followed by Liangshan and Aba. Our findings also depicted a high equality in Panzhihua and Ziyang since most counties within these regions had similar levels of spatial accessibility to the nearest emergency facilities.

In terms of the proportion of population living within 15-min travel time (Figure 6), large geographical disparity was still observed at prefecture and county levels. In 13 prefectures, *e.g.*, Chengdu, Deyang, Guangan, and Suining, more than 80% of their population were found to reside within 15-min travel time to the nearest emergency healthcare facility, while less than 30% of population live within this threshold in Ganzi. Another seven prefectures, including Aba, Liangshan, Yibin, Luzhou, Guangyuan, Bazhong and Yaan, showed less than 80% of the population residing within 15-min travel time of an emergency healthcare facility. The outcomes also revealed significant difference in the proportion of residents at the county level within some prefectures, especially in Leshan, Liangshan, and Ganzi.

Regression results

We performed conventional OLS regression to identify the association between social-economic characteristics and the shortest travel time to nearest emergency healthcare facility at the county level. We expanded the initial model (no. 1) by including area, GDP and urbanization rate step by step to examine how robust the

estimates were. Table 4 present these results and its corresponding goodness of fit. Appendix Table 1 shows the results of collinearity diagnostics. In the Appendix Table 1A, we found an acceptable
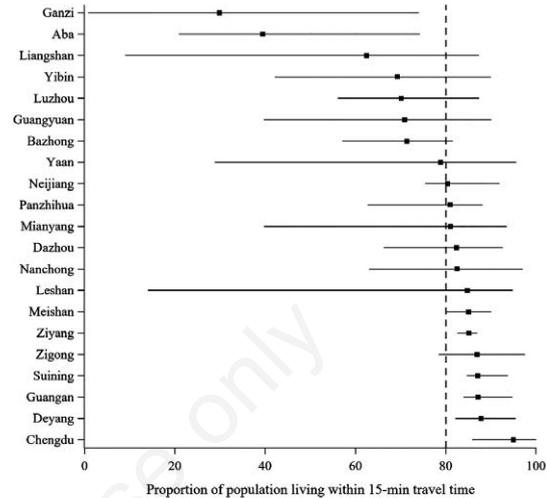
The points (squares) refer to the proportion of population within 15-min travel time in each prefecture. The intervals refer to the range of the proportion of population within 15-min travel time at the county level.

Figure 6. Proportion of population living within 15-min travel time in 21 prefectures in Sichuan Province.

Table 4. Regression results for shortest travel time at county level in Sichuan province.

Variables	Model 1	Model 2	Model 3	Model 4
Intercept	2.861*** 0.074	2.310*** 0.083	9.652*** 0.783	7.763*** 0.819
Population, per 10,000	-0.014*** 0.001	-0.009*** 0.001	0.002 0.002	0.001 0.002
Area, per 1000 km^2		0.123*** 0.013	0.051*** 0.013	0.052*** 0.012
Log of GDP			-0.471*** 0.05	-0.318*** 0.055
Urbanization rate, %				-0.012*** 0.002
R square	0.392	0.598	0.731	0.766
Adjusted R square	0.389	0.584	0.727	0.761
N	183	183	183	183

*** 1% significance levels; **5% significance levels; *10 % significance levels.

Appendix Table 1. Collinearity diagnostics of all included independent variables.

	Variable	SE*	t	P	VIF**
Intercept	7.763	0.819	9.48	<0.001	-
Population, per 10,000	0.001	0.002	0.39	0.6975	3.371
Area, per 1000 km^2	0.052	0.012	4.26	<0.001	1.890
Log of GDP	-0.318	0.055	-5.73	<0.001	6.481
Urbanization rate, %	-0.012	0.002	-5.16	<0.001	2.066

*Standard error; **variance inflation factor.

VIF that was <5 in the included variables except the logarithm of GDP that, however, was <10B suggesting that there was no severe collinearity in the regression model. Therefore, the regression results can be considered to be stable and we included all the variables. In model no. 1 (Table 4), echoing our hypothesis, the number of population showed a significant negative association with shortest travel time (β=-0.014, <0.001), suggesting that counties with higher population distributions tend to have a better accessibility to the nearest emergency healthcare facility. After adjusted the area in model no. 2, we found that it was positively associated with the shortest travel time (β=0.123, <0.001) and that there was a slight increase in the estimated coefficient for population size. However, the estimated coefficient turned out to be positive and insignificant at the level of 10% significance after including GDP per capita in model no. 3. The results reveal that logarithm of GDP have a significant negative association with the shortest travel time (β=-0.471, <0.001), which indicates that the association between population and travel time could be largely attributed to GDP. After including the urbanization rate in model no. 4, the logarithm of GDP and urbanization rate were both significantly negatively associated with the shortest travel time (β=-0.318, <0.001; β=-0.012, <0.001). That is to say that a 10% increase in GDP was associated with a 3.2% decrease in average shortest travel time, while a 10% increase in urbanization rate was associated with a 12% drop. These findings are consistent with our hypothesis and demonstrate that accessibility of emergency healthcare facilities is strongly associated with the social-economic development. Another significant factor contributing to the shortest travel time is the county area (β=0.052, <0.001) and the coefficient indicates that counties with large administrative areas tend to have larger travel times on average.

Discussion

Spatial accessibility is widely recognized as a key component in the evaluation of a population's overall access to healthcare, especially in the aspect of emergency care. Understanding the time impedance from population to emergency services has a great potential in promoting public health issues. Moreover, a better illustration of geographical disparities in spatial accessibility of emergency care is expected to assist decision-making in future healthcare planning.

This paper reported an averaged travel time of 6.9-minute to the nearest emergency facilities in Sichuan, and indicated that 80% (66.73 million) of the population can access the emergency services within 14.6 minutes. According to the benchmark set for 2030 where at least 80% of the population are expected to reside within 2-hour travel time from emergency medical services (Ouma et al., 2018), Sichuan remains far below target. In China, emergency medical service systems in many provinces have been developed with the aim of constructing a "15-minute emergency response circle". The emergency centres in urban areas are required to be located in order to reach a service radius of 3-5 km allowing the average emergency response time to be shortened to 10-15 minutes. In sharp contrast to urban regions, the average emergency response time increased to 15-20 minutes in suburban and rural areas with an expanded service radius between 8 and10 km. Our findings suggest that more than 80% of the residents in Sichuan would be able to live within the "15-minute emergency response circle".

Despite a relatively high level of overall spatial accessibility to emergency care, a strikingly uneven distribution of emergency healthcare accessibility remained throughout the province, with the eastern area presenting much higher accessibility than the western one. This geographical pattern was consistent with previous literature sources focusing on hospital care and primary care in Sichuan (Wang et al., 2018; Pan et al., 2016). Healthcare resource supply and road networks are highlighted as two crucial contributors for residents' obtaining timely and fully access to healthcare (Mathison et al., 2013; Wang et al., 2018). Historically, compared with eastern Sichuan, the western part of the province remained at disadvantaged economical position, especially with respect to road network construction and population density. The pattern of emergency facility distribution (Figure 3) also presented predominant preference towards eastern Sichuan. All these factors would result in a much lower level of spatial accessibility to emergency care in western Sichuan. As the key determinant to healthcare utilization, spatial accessibility would have significant impact on the overall population's health outcomes, especially on tackling with life-threatening conditions. Evidence from empirical studies shows a higher maternal mortality ratio (MMR) in western Sichuan where ethnic minorities are densely situated compared with the eastern part, while the average shortest travel time to the nearest hospital was adopted as the indicator reflective of the disparities in MMR. (Ren et al., 2017). Thus, geographical disparities in spatial accessibility are likely to induce discrepancies in healthcare outcomes.

Our analysis indicates that at the county level, local economic development, urbanization level and administrative area demonstrate significant association with spatial accessibility of emergency care. In particular, GDP per capita and the urbanization rate were both found to be indicators reflective of socio-economic level in China. Our findings suggest that higher GDP per capita, as well as a larger proportion of urban population, were associated with a better spatial accessibility to emergency care. In China, emergency care is mainly provided by qualified hospitals in urban areas and the THCs/CHCs in the rural areas. These facilities were seen as more likely to be located at developed areas with higher population density and relatively well-constructed road networks, thus greatly enhancing the efficiency of emergency healthcare delivery to most of the residents. As the result, people living in those areas obtain a much higher level of spatial accessibility. Moreover, the estimated coefficient of population counts indicates that more densely distributed populations have a higher spatial accessibility, while the association tend to be attenuated after adding GDP into the model. This finding partly reflects that the local economic development serves as an important stimulant to improving local spatial accessibility of emergency care. In addition, our results show that on average, counties with larger administrative areas tend to have lower spatial accessibility as verified by Figure 2, where larger, rural counties in western Sichuan, such as Ganzi, Aba and Liangshan, are characterized by sparse populations and an underdeveloped economy.

Since the announcement of "Healthy China 2030" planning, outlined by the Central Party Committee and the State Council in 2016 (Tan et al., 2017), China's government is actively improving the emergency medical service system as well as promoting the capacity and efficiency of emergency care based on one a core principle of fairness and justice. Special attention needs to be paid on rural and underdeveloped areas, in order to facilitate equal access to basic public health services as well as maintaining public welfare. Our paper provides empirical evidence on the spatial

accessibility of emergency care, and the findings are essential for policy makers. To mitigate the regional disparity in accessibility of emergency care in Sichuan, it is strongly recommended that constant efforts be made on planning and allocation of healthcare resources. Fortified financial support needs to be encouraged at the provincial and central governmental levels to enhance the emergency healthcare delivery in underdeveloped areas in western Sichuan, especially for Ganzi and Aba. In addition, proposal of policies and strategies by the central government could also be adopted to attract healthcare workforce to such underdeveloped areas, thus propelling the development of local emergency medical service systems. Other specific policies, such as tax benefit policies could be adopted as an incentive for stimulating the expansion of private hospitals, especially in western Sichuan. Despite the predominant role of the public healthcare facilities in emergency healthcare delivery in Sichuan, private facilities are indispensable supplements with respect to improving the overall spatial accessibility to emergency care across the province. Apart from general financial support and optimized healthcare resources, investments could also be made at various government levels, *e.g.*, road construction in western Sichuan. Moreover, the improvement of emergency healthcare capacity must be emphasized in order to achieve equity in population's health outcomes. From the perspective of public healthcare education, first-aid training programmes are highly encouraged as an essential strategy for raising public awareness towards the importance of emergency care, as well as equipping residents with the necessary emergency healthcare skills. In the underdeveloped areas where low spatial accessibility dominates, essential first-aid help could significantly reduce the mortality of life-threatening conditions and improve their prognosis.

We recognize that this study has several limitations. First, we focused on spatial accessibility to emergency care, which solely reflects the ability for people to reach the emergency system within an acceptable time. We assumed here that all residents obtain the emergency care required and ignored the actual pattern of healthcare utilization, such as patients' preference. Thus, the work presented is limited to reveal the realised accessibility to emergency care. Second, we admit that there are differences in the quality of emergency care between different levels of hospitals, and between facilities in urban and rural regions. As we focused on the most general emergency conditions, disparities in the quality of emergency care would have a minor impact on the patients unlike in life-threatening cases. Stratified analysis for different levels of emergency care will be conducted in future studies. Third, the established linear model is quite simple and only considers few socio-economical characteristics. There remains the possibility for unobserved factors that could contribute to the spatial accessibility to the nearest emergency healthcare facility at the county level. More valuable indicators need to be considered in future studies.

Conclusions

This paper provides a brief introduction to China's emergency medical service system assessing the spatial accessibility of emergency care and its associated social-economic characteristics in Sichuan Province. Our findings report a relatively high level of overall spatial accessibility to emergency care across the province, with the eastern area presenting a higher accessibility than the western area which demonstrated substantial geographical disparity. The county-level discrepancies in accessibility could be signif-

icantly attributed to the variance of local economic development, urbanization level and administrative area. Such findings are expected to provide evidence-based implications for future policy-making process. In order to bridge the gap of spatial accessibility among different regions in Sichuan, it is highly advocated that a constant effort be made at the central governmental level to optimize the allocation of healthcare resources through continued, strong financial support with preferential policies for economically underdeveloped regions. Last but not least, improvement of emergency healthcare capacity needs to be addressed as a long-term solution for achieving equality in the residents' healthcare outcomes in a holistic perspective.

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