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Research Review on the Equity Evaluation of Medical and Health Resources Allocation from an International Perspective

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Abstract **Review Article**

The Corona Virus Disease 2019 (COVID-19) has affected countries all over the world, causing more than 200 million people infected with 4 million of deaths, which poses a great threat to the world's economic and social development, and also warns the medical and health resources in various countries. Based on an international perspective, a summary of the fairness of medical and health resources allocation is conducive to further promoting relevant research in various countries, formulating development plans for medical and health service system, and accelerating the equalization of basic health services. On the basis of expounding the research background and significance of medical and health resources allocation, this paper summarizes the main research contents and methods of international and China in this field through literature analysis. It is found that studies abroad mainly focus on the fairness of medical and health resources allocation and the factors affecting its fair allocation and spatial accessibility, while research in China mainly focuses on the spatial and temporal differentiation characteristics, influencing factors and spatial accessibility of medical and health resources allocation. Further study should emphasize the universality and objectivity of the research area and scale, construct the comprehensive index system of influencing factors and analyze the mechanism of each factor.

Keywords: Medical and health resources; allocation fairness; influencing factors; spatial accessibility; spatio-temporal variations.

1. INTRODUCTION

With the sustainable development of economy and society, the residents' health awareness has gradually increased, and the conflict between the people's demand for high-quality medical and health resource and the unbalanced and insufficient supply of medical and health resources has become increasingly prominent. It requires to pay attention to optimizing the allocation of medical and health resources and promoting the fairness of medical and health resources. The Corona Virus Disease 2019 (COVID-19) has swept 215 countries around the world since 2020, with more than 200 million confirmed cases and 4 million dead cases. It posed huge threats to the health of people around the world, and impacted on the social stability. It is a severe challenge China is facing whether Chinese can consolidate the victory of fighting against COVID-19, achieve green and low-carbon economic development, and build the modern powerful socialist country. Not only Healthy China Strategy but also a series of development plans for the health service system illustrate the increasingly attention to the livelihood issue of basic medical and health services. However, the overall investment of medical and health resources in China is insufficient and the allocation is unequal, the gap of public medical services between urban and rural areas, regions, and levels is too large, and social problems such as difficult and expensive medical treatment are still severe. It is conducive to promoting the integrated development of urban and rural areas to establish a balanced allocation mechanism of medical and health resources in urban and rural areas, and to promote the inclusive sharing of urban and rural medical and health services [1]. It contributes to improving public services and supporting regional high-quality development that constructing the regional coordinated development pattern of balanced medical and health resources allocation [2]. The establishment of a hierarchical diagnosis and treatment system is conducive to promoting the grassrootization of medical

resource, strengthening the rationality of resource allocation, and meeting the people's needs for basic medical and health services [3]. In summary, optimizing the allocation of medical and health resources is a hot issue that needs to be improved in current theoretical research and management practice in medical and health field.

The medical and health resources allocation is a key field of research both in China and abroad at present. Using CNKI and Elsevier, a large amount of literature in this field since the 21st century was collected, especially in the past five years. After extended reading and combing, the main research contents of the literature were classified, and the methods and indicators in each research content were elaborated. Analyzing the deficiency of current research, including the research hot-spots and mainstream methods, discussing the future research directions, this paper provides guidance for further research based on the urgent problems and the development prospects. The scientific and reasonable allocation of medical and health resources and the effective improvement of the fairness of resource allocation are important foundations for the substantial development of health service. Therefore, research in this field has certain practical significance, and provides policy recommendations for various countries to strengthen the macro-control of the allocation of medical and health resources, to meet the basic needs of the masses, and to improve the equalization of public health services.

2. RESEARCH ABROAD

2.1. Equity of Medical and Health Resources Allocation

It has reached consensus that citizens should enjoy medical and health resources universally and equally, but there is still no consensus on the definition and standard of equitable access to medical resource. To achieve the fairness in the allocation of medical and health resources, a unified definition and measurement criteria should be formed according to the scope and quality of medical facilities, the convenience and cost of patients accessing to medical services. Therefore, indicators such as per capita resource ownership and equal use right were introduced to measure the fairness of regional medical and health resources allocation [4-6]. In the research process, a variety of methods have been used to calculate the fairness of medical and health resources allocation, in which the Gini coefficient and Lorenz curve are the most widely used [7-10]. In addition, some new methods were explored to equitably allocate medical and health resources. Theodorakis *et al*., studied the inequality of human health resources allocation in Albania by plotting the Lorenz curves and calculating the Gini, Atkinson and Robin Hood indices and decile ratios, both before and after adjusting for mortality and consultation rates [11]. McIntyre *et al*., studied the fairness of health resources allocation in small regions of poverty-stricken South Africa by constructing deprivation index [12]. Augustine *et al*., studied the equality of resources allocation between the Ashanti and Northern Regions of Ghana, selected multiple indicators to construct the deprivation index, and used principal component analysis, Spearman and Pearson's correlation analysis to study the fairness of medical and health resources allocation in the two regions, providing reference for the study of the fairness of resource allocation in small regions [13]. Macharia *et al*., studied the configuration of long-lasting insecticidal nets (LLINs) in eight counties in western Kenya, using indicators such as estimated travel time, socioeconomic and antenatal care attendance data to define the actual requirements of LLIN. Through the establishment of geocoded database of public health facilities and network analysis methods, it was confirmed that there were important inequalities in the distribution of LLINs in Kenya [14]. Eyob *et al*., argued that the historical incrementalist method of budgeting/resource allocation led to unequal distribution of health resources in Namibia. They used the principal component analysis to develop a needs-based resource allocation formula from the asset based and health-related variables. This allocation mechanism was considered to evaluate the actual medical needs and solve uneven resource allocation [15]. Mostafavi *et al*., calculated Concentration Index, Concentration Curve, and Horizontal Inequality index to measure inequality in inpatient and outpatient health care utilization in Iran. The results showed that inpatient services were fair and outpatient services were concentrated in the rich. Rural areas showed lower inequality in inpatient services, while non-rural areas have lower inequality in outpatient services [16]. Selcen *et al*., calculated the concentration index and horizontal equity index of Turkey from 2008 to 2012, and used the Blinder–Oaxaca decomposition analysis to investigate the degree and progress of equity in medical and health utilization [17]. James *et al*., addressed four issues in the allocation of medical resource: (i) the degree of inequality; (ii) do government health expenditure benefit the worst-off; (iii) can government health spending more effectively promotes equity; and (iv) measures to reduce inequality, and the main methods and data used are reviewed. Their research provides reference and support to use quantitative analysis methods to solve the main social problems [18]. Using different research methods, a large number of studies have shown that the uneven distribution of medical resource is widespread around the world, and the scarcity of medical resources in rural areas and remote areas is more serious (Table 1).

Table 1: A literature review on equity of medical and health resources allocation

Authors	Year	Area	Motheds	Results
Chang, R.K. [7]	1997	Fifty States and Washington, DC in US	the Gini coefficient and Lorenz curve	The distribution of pediatricians in US was unbalanced, and there were still significant differences between states in the distribution of pediatricians relative to population.
Bidgoli, H.H. [8]	2010	Iran	the Gini coefficient and Lorenz curve	Road traffic mortality (RTM) and road traffic injuries (RTIs) as well as prehospital trauma care facilities were distributed unequally between different provinces. The distribution of prehospital trauma care facilities did not reflect the needs in terms of RTM and RTIs for different provinces.
Brown, M.C. [9]	1994	Alberta in Canada	the Gini coefficient	There were differences in the spatial distribution of health practitioners among rural, town and urban areas. Health practitioners most distributed in urban areas and least in rural areas.
Horev, T. [10]	2004	US	the Gini coefficient	In the past 30 years, the fairness of hospital beds distribution in American states has increased, the fairness of doctor distribution has decreased. Physicians' distribution exhibited a geographic trend, and the fairness between rural areas and regions with low economic development was poor.
Theodorakis, P.N. [11]	2006	Albania	the Lorenz curves, the Gini coefficient, Atkinson indices, Robin Hood indices and decomposition ratios	There was a declining trend in the inequality of distribution of general practitioners in Albania in 2000-2004.
McIntyre, D. [12]	2002	South Africa	the deprivation index	The allocation of medical health resources in rural and poor areas was insufficient.
Asante, A.D. [13]	2006	the Ashanti and Northern Regions of Ghana	the principal component analysis, Spearman and Pearson's correlation analysis	The deprivation index in rural areas and remote areas of Ghana was high, and medical health resources in these regions were deficient.
Macharia, P.M. [14]	2017	Western Kenya	the geocoded database of public health facilities and network analysis methods	There were important inequalities in the distribution of medical health resources in Kenya, 36% of the clinics had more resources than what was needed (over-allocated) while 43% had received less (under-allocated).
Zere, E. [15]	2007	Namibia	the principal component analysis	The allocation of medical health resources in Namibia was unequal, and there are fewer resources available in high demand areas than low demand areas.
Farideh, M. [16]	2020	Iran	the Concentration Index, Concentration Curve and Horizontal Inequality index	Iranian inpatient services and outpatient services in rural and non-rural areas were unfair. Inpatient services were relatively fair and outpatient services were concentrated in the rich.
Öztürk, S. [17]	2020	Turkey	the concentration index, horizontal equity index and the Blinder–Oaxaca decomposition analysis	Equity in utilization of health care services in Turkey showed a growing trend during 2008-2012, the general practitioner, specialist and inpatient visits displayed a pro-poor orientation.

2.2. Factors Affecting Fair Allocation of Medical and Health Resources

The fairness of the allocation of medical and health resources is directly related to people's health. Fair allocation of medical and health resources is essential for a country or region to ensure the life and health of its residents [19]. So exploring the factors that affect the fairness of medical and health resources allocation becomes an important content. Chang et al. determined the factors affecting the allocation of human resource through regression analysis. It was shown that the geographical distribution of pediatricians was related to marketplace changes, changes in the health needs of children and adolescents, and changes in the demographic profile of trainees and the number receiving subspecialty training [7]. McIntyre and Augustine *et al.*, found that regions with poor resource allocation were mainly concentrated in rural and impoverished areas, and then established regional resource allocation evaluation mechanism nationwide. That means the regions need to increase resource allocation could be recognized by evaluating the degree

of poverty in the region [12, 13]. By regression analysis, Horev *et al*., confirmed that the distribution of doctors was positively correlated with the distribution of beds, and income inequality was positively correlated with the inequality of doctors and beds [10]. Mostafavi *et al*., used the decomposition analysis to measure the factors affecting the fairness of resource allocation. It was shown that the non-need factor was important, especially the lack of supplementary insurance and socioeconomic status [16]. Analyzing the public spending and benefit incidence on curative health care in several African countries, Castro-Leal *et al*., measured the impact of government health expenditure on personal interests. It was shown that most curative health subsidies in Africa were not particularly well targeted to the poorest, and the health services enjoyed by the poor were impacted by income, service quality, access and opportunity cost, price, gender [20]. Nyamande *et al*., used the Binomial regression intersectional approach to estimate the impact of gender and education level on the inequality of health care utilization. There was a complex interaction between gender and educational inequality in access to care in northern Sweden. Women with low education used health services more frequently than men, and gender inequality prevented men from accessing primary care [21]. The factors affecting the allocation of medical health resources are multifarious. Among them, economic development is the most important factor. Furthermore, the difference of social environment, residents themselves and government policies will also have a certain impact on the uneven distribution of medical resources (Table 2).

Table 2: A literature review on factors affecting fair allocation of medical and health resources

Authors	Year	Area	Influencing factors	Results
Chang, R.K. [7]	1997	Fifty States and Washington, DC in US	number of doctors, number of beds, gender of pediatricians, education degree of pediatricians, medical insurance payment, income, participation in health organizations, residence	The changing health care marketplace, pediatric training programs and the health needs of children and adolescents had important implications for the allocation and geographical distribution of pediatricians.
Horev, T. [10]	2004	US	median income, the income Gini, the geographic location, the rates of physician and hospital-beds per capita	The allocation of medical health resources in US states was related to income, geographical location and the rates of physician and hospital-beds per capita, and there was a marked association between inequality of income and inequality of physicians and hospital-beds.
McIntyre, D. [12]	2002	South Africa	residence, age, economic status, gender, working status, family status, living environment, education degree	The relationship between socioeconomic status and the health of residents and the allocation of medical health resources was closely related, medical health resources in the poverty-stricken area of South Africa were insufficient.
Asante, A.D. [13]	2006	the Ashanti and Northern Regions of Ghana	residence, gender, age, health status, work status, education level, living environment	Regional medical health resources allocation was closely related to its social economic development, in addition, the difference in residents' individual conditions also had a certain impact on resource allocation.
Farideh, M. [16]	2020	Iran	Need factors include demographic variables (age and sex) and a health variable (self-reported health), non-need factors include socioeconomic status variables, education, basic and supplementary insurance, marital status, and occupation.	Non-need factors were the most important contributors to explain both inpatient and outpatient inequalities, and among them, the lack of supplementary insurance and socioeconomic status were the most important explanatory factors.
Castro-Leal, F. [20]	2000	Côte d'Ivoire, Ghana, Guinea, Kenya, Madagascar, South Africa, and the United Republic of Tanzania	income, service quality, access and opportunity cost, price, gender	Resident's income was the most basic factor affecting residents to obtain medical health services. The high service quality, the low cost and price would promote residents to obtain medical health services. In addition, serious inequality was produced in the distribution of health benefits by gender.
Fortune, N.N. [21]	2020	northern Sweden	gender and educational degree	This study suggested a complex interaction of gender and educational inequities in access to healthcare in Northern Sweden.

2.3. Spatial Accessibility of Medical and Health Resources

The uneven distribution of medical and health resources leads to spatial inequality in the health sector. In order to achieve equitable allocation of basic medical services, it is essential to measure the geographical spatial accessibility of medical and health resources [19, 20]. The accessibility of medical services is one of the main objectives in many national health plans and strategies [24]. Amritpal *et al*., remedied the defect of the traditional accessibility research on the assumption of universal car access, fully considered the multi-modal mean of travel, and used Spatial Access Ratio method to simulate walking, multi-modal transport and driving at the community level to analyze the spatial accessibility of primary health facilities [22]. With geographic information system (GIS), Shunsuke *et al*., constructed a Patient Access Area Model (PAAM) to simulate the time of patients visiting medical institutions and evaluate the balance between future medical service demand and supply [25]. Dumitrache *et al*., used the index of spatial accessibility to quantify the population's accessibility to public hospitals as the shortest time from the settlement centroid to the nearest hospital, and explored the potential geographic availability of the Romanian population to public hospitals [26]. Gharani *et al*., investigated the spatial accessibility of in vitro fertilization treatment in Iowa, the United States, and constructed accessibility index to examine the impact of the variables on accessibility and further reveal potential underserved areas by means of a modified gravity model and techniques from spatial interaction modeling. The accessibility index contained three key socio-demographic variables, which were female age, median household income and race/ethnicity [27]. Stentzel *et al*., believed that the mobility of the elderly in rural areas was limited and the accessibility of public transport was very important. On the basis of network analysis within GIS, they used network analysis based on Dijkstra algorithm to study the accessibility of general practitioners and specialists physicians through cars and public transport in sparsely populated rural areas in northeast Germany [28]. Takashi et al. used distance measures and the Enhanced 2-Step Floating Catchment Area (E2SFCA) method to compare the number of community hospitals and the scores of E2SFCA in terms of hospital quantity and fairness, and concluded that some community hospitals were located in areas with less population and needed to be adjusted [23]. In addition, 2-Step Floating Catchment Area method was also widely used. Deborah *et al*., used the improved 2-Step Floating Catchment Area method and Gaussian distance-decay function, combined with GIS technology, to study the geographical accessibility of representative medical services for the elderly in Singapore, and further analyzed the main factors leading to cold spots and hot spots [24]. The research on spatial accessibility of medical and health resources is helpful to the adjustment of existing unreasonable layout and the planning of future development.

3. RESEARCH IN CHINA

3.1. Analysis on the Spatial-Temporal Variations of Medical and Health Resources Allocation

Regarding allocation of medical and health resources, the research perspective focused on the spatial-temporal variations of resources allocation, and carried out research from hierarchical differences and regional differences. Besides, difference between urban and rural was a highlight of regional differences. The polarization of medical and health resources allocation in China was especially prominent in the polarization between rural and urban areas. Basic medical facilities and health resources in rural areas were seriously inadequate, and health investment was also lower than the national average [29, 30], urban and rural medical and health resources had non-equilibrium characteristics in the allocation of material, human, and financial resource [1]. The polarization of medical resources allocation between primary medical institutions and large-scale hospital in China was prominent, which was manifested in the inverted triangle allocation of medical resources among multi-level healthcare institutions. The hospital system concentrated most of resource, while the allocation of primary institutions was insufficient [3, 31]. The unreasonable regional allocation of medical resources in China was obvious. A large number of high-quality medical resources were concentrated in large cities and central areas [3]. Based on the national scale, the resources were more in the east and less in the west, and the degree of non-equalization among regions was also different [2,29]. Zou Wenjie *et al.*, found that the equalization of medical and health services in China had obvious spatial-temporal differentiation characteristics, with spatial dependence, and the changes in provinces were different [32]. Based on the small regional scale, many scholars studied the characteristics of medical and health resources allocation in different provinces and cities, providing ideas of improving the fairness of regional resource allocation [3, 33-36].

There were many methods to measure the allocation of medical and health resources. The main measurement methods were Gini coefficient, Lorenz curve [2], Theil index [1, 3] and the amended weighed coefficient of variation [1, 31]. Other mathods such as the comprehensive index dispersion method [32] and the rank sum ratio comprehensive evaluation method [34] were used as the measuring tools too. In addition, Wang Gaoling *et al*., used agglomeration degree to evaluate the agglomeration characteristics of medical resources [33]. Zhou Chao et al. used entropy to measure the general characteristics of the basic public service facilities level [35]. Yang *et al*., used the

improved Huff model to evaluate the matching degree of public medical service level [36].

3.2. Analysis on Influencing Factors of Medical and Health Resources Allocation

Existing research has shown that regional political, economic and social conditions do impact on the allocation of medical resources. Exploring the influencing factors of regional resources allocation is conducive to providing targeted policy recommendations for regional health planning. Therefore, scholars have specifically analyzed the influencing factors of resource allocation, in which the main methods adopted were fixed effect model [31], geographical detector model [3], state space model [41] and spatial regression model [31, 33, 36].

The influencing factors of balanced allocation of medical and health resources were diverse. The empirical analysis results have confirmed that the main factors were economic development level [3, 29], financial transfer payment system [29, 33], public health expenditure intensity [1, 33], population density [3, 33], and so on. Based on household registration system, unified standard of basic public service supply, division of labor and accountability system, diversified social participation mechanism and effective supervision mechanism, Guo Lan discussed the reasons for the non-equalization of basic public services in China [29]. Lv Guoying *et al*., believed that the urban-rural dual structure caused significant difference in the allocation of medical and health resources. The behavior of medical treatment in large farmer hospitals strengthened the adverse selection of rural medical field and further polarization of urban and rural medical resource allocation. They argued that the government-dominated hospital rating system, the rigid personnel system and the fixed-point practice system were major institutional factors contributing to the geographical maldistribution of physicians in China [30, 31]. The empirical analysis results of Yang Lin et al. showed that the output gap of medical services and medical preference affect the benefit degree of residents' medical security [1]. Song Xueqian *et al*., evaluated the mechanism of population distribution and structure, economic development level, topographical conditions and disease incidence on the spatial allocation of upper-level and basic-level healthcare resource [3]. Yang Boxue *et al*., believed that the average fixed assets of medical and health institutions were negatively correlated with medical and health resources allocation, and the density of medical and health institutions was positively correlated with resource allocation [36].

3.3. Spatial Accessibility Analysis of Medical and Health Resources

The goal of equalization of basic public health services can be transformed into that residents can reach basic medical and health service nodes within acceptable time, so the equalization of medical and health services can be interpreted as the spatial accessibility of service nodes relative to residents [32]. The conventional spatial accessibility methods were minimum distance method, layout optimization model, potential model and 2-Step Floating Catchment Area (2SFCA) method.

The minimum distance method takes straight-line distance or traffic distance to calculate the distance or time of residents arriving at the nearest public service facilities, which just reflects the spatial accessibility of facilities, but not the service quality and scale of facilities, population distribution characteristics, residents' needs and choices [37]. The layout optimization model based on mathematical model was widely used in regional health planning, which could select the appropriate location from a batch of candidate locations to construct health service facilities. Cumulative opportunity model [38] and isochrone model [39] were commonly used in this kind of model. The potential model evaluates the accessibility of medical facilities by calculating the attractiveness of medical facilities to residents in the region, and scholars have continuously improved it. Cheng Min and Song Zhengna *et al*., introduced the population scale factor and the medical facility grade scale influence coefficient to modify the potential model [40, 41]. The 2SFCA method conducts two mobile searches centered on supply and demand, and evaluates the rationality of regional facilities layout by calculating the number of facilities or resource that residents can reach according the cost distance settings. Zhong Shaoying constructed the 2-stage 2SFCA method to analyze the spatial accessibility of medical facilities at different referral rates [42]. Liu Ze *et al*., introduced the kernel density function to model distance decay, and improved the 2SFCA method based on issues such as competition among medical facilities, inadequate exploitation of medical services, and different standards of services from hospitals in various levels [43].

4. REVIEW

This paper summarizes the main research contents in the field of medical and health resources allocation in China and abroad. The key research directions abroad are concluded as the fairness of medical and health resources allocation, the factors affecting its fair allocation and spatial accessibility, while the main research hotspots in China focus on spatial-temporal differentiation characteristics, influencing factors and spatial accessibility. It also introduces these aspects and application methods in detail. Scholars have paid more attention to the research on the medical and health resources allocation. They have carried out multi-dimensional research on the differences in resource allocation, considered the factors causing unbalanced resource allocation in many aspects, and comprehensively used various methods for

analysis. Despite all this, there are still some questions worth discussing in current research.

In terms of regional selection, metropolis were often selected for analysis, while small and medium-sized cities were little involved. Can metropolis be representative regions? Since inequality is greatly affected by economic conditions, will there be other distribution characteristics and laws in small and medium-sized cities? In terms of scale, considering the limitations and convenience of data acquisition, current studies mostly takes administrative units such as cities, provinces, or even larger regions as research area. Research on smaller spatial scale such as countries is rare. Whether the allocation of medical and health resources in a wide range masks the characteristics and laws of that in small-scale area? Are their influencing factors consistent? What's more, due to the large scale, the administrative center is mostly selected as the regional center rather than the population gravity center. Is the results deviation caused by center selection too small to be ignored? Future research should choose different regions and scales, collect complete data and refine the research scale, so as to make the results more scientific and universal.

In terms of influencing factors analysis, current research focus on some aspects of geographical environment, especially economic factors, while lacks comprehensive analysis of multi-faceted influencing factors. And meanwhile, only the correlation and influence degree between factors and allocation are analyzed, and the mechanism is not deeply explored. Future research should construct a comprehensive index system based on physical geographical conditions, socioeconomic level, policy system and living environment, analyze the comprehensive function of each factor and clarify their mechanism. It could be beneficial to put forward objective and reasonable adjustment suggestions for optimizing resource allocation and improving fairness of public service.

In terms of accessibility analysis, firstly, it is one-sided to select one or other single indicator to characterize the service capacity of medical facilities. Secondly, the selection of travel barrier coefficients is subjective. Furthermore, Euclidean distance was taken as evaluation criterion, which means the influence of geographical and traffic conditions was ignored. Last but not least, there are few analysis of cross-regional medical behavior. So further study should construct the comprehensive evaluation index system to measure spatial accessibility. Then the actual travel resistance should be obtained through the big data regression analysis of residents' medical travel. In addition, the appropriate research methods should be selected according to the regional reality and the applicable conditions of each method. What's more, the residents' actual medical choice should be analyzed through questionnaire survey and visit.

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