


The Efficiency Evaluation of Municipal-Level Traditional Chinese Medicine Hospitals Using Data Envelopment Analysis After the Implementation of Hierarchical Medical Treatment Policy in Gansu Province, China

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Yuanyuan Li, MMed¹ , Yongqiang Zhao, MBBS¹, Xixin Niu, MBBS¹, Wei Zhou, MSc¹, and Jun Tian, MMed¹

Abstract

Background: Efficiency evaluation is an integral part of new medical reform and is necessary to solve the problem of limited and unbalanced medical resources. This study evaluated the efficiency of municipal-level Traditional Chinese Medicine hospitals by Data Envelopment Analysis application after a hierarchical medical treatment policy was implemented. We propose solutions to the problems existing in hospital operations and promote the utilization efficiency of medical resources in those hospitals. **Methods:** The sample included all municipal-level TCM hospitals in Gansu province from 2017 to 2019. The DEA-BCC model was employed to evaluate the relative efficiency of hospital operations, and the Mann-Whitney test was used to compare the input and output variables of technical efficiency efficient and inefficient hospitals. **Results:** From 2017 to 2019, the growth in the number of staff in secondary hospitals (25.88%) was lower than that in tertiary hospitals (31.98%). However, the increase in the number of beds (16.52%) in secondary hospitals was higher than that in tertiary hospitals (−0.30%). 5 (38.46%) achieved DEA efficient in secondary hospitals and 2 (40.00%) in tertiary hospitals. The means of technical efficiency, pure technical efficiency, and scale efficiency in secondary hospitals were 0.812, 0.887, and 0.908, respectively. The means in tertiary hospitals were 0.868, 0.926, and 0.935, respectively. The hospital areas were statistically different between the TE efficient and inefficient hospitals ($P < 0.05$) in secondary hospitals. However, the number of outpatients between the two groups was statistically different ($P < 0.05$) in tertiary hospitals. **Conclusion:** In this study, the medical and health services of municipal TCM hospitals in Gansu Province have made great progress. Due to the backward economy of Gansu Province, the classification of diagnosis and treatment of diseases was still based on Western medicine, resulting in the slow medical development of some municipal TCM hospitals. TCM hospitals should improve management efficiency, optimize hospital operation scale, improve the utilization efficiency of medical resources and promote efficient hospital development.

Keywords

data envelopment analysis, return scale, management policy, traditional Chinese medicine hospitals, efficiency evaluation

¹Gansu Provincial Hospital of Traditional Chinese Medicine, Lanzhou, China

Corresponding Author:

Yuanyuan Li, Gansu Provincial Hospital of Traditional Chinese Medicine, 518 Guazhou Road, Qilihe District, Lanzhou 730050, China.

Email: li-yoyo@163.com

Xixin Niu, Gansu Provincial Hospital of Traditional Chinese Medicine, 518 Guazhou Road, Qilihe District, Lanzhou 730050, China.

Email: 8414099272@qq.com



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What Do We Already Know About This Topic?

Previous studies have shown that efficiency evaluation is an important part of new medical reform and is necessary to solve the problem of limited and unbalanced medical resources.

How Does Your Research Contribute to the Field?

This study aimed to evaluate the efficiency of municipal-level TCM hospitals after a hierarchical medical treatment policy was implemented, evaluate the relative efficiency of hospital operations, and determine the influencing factors of hospital efficiency using data envelopment analysis.

What Are Your Research's Implications Towards Theory, Practice, or Policy?

The government should strive to narrow the gap in the utilization efficiency of medical resources in different regions. Hospital managers should improve management's ability to promote the effective use of medical resources and pay attention to the introduction and training of professional and technical staff. This will result in improved medical technology ability and management ability.

Introduction

Healthcare reform is a challenging global issue, made more complex for China as a developing and populous country. Accompanied by aging, urbanization and other social and economic transformation process in China, the current medical service system remains irrational in medical treatment and resource allocation areas. The government and healthcare providers must improve the productivity, efficiency, and quality of medical and health service institutions to achieve comprehensive and balanced development of the public service system.¹ In the past few years, the government has formulated a series of public health care reform policies to promote the consistent long-term development of medical and health services and improve people's health. To overcome the saturation of high-quality medical resources and slow development of basic medical institutions in big cities, China began implementing a graded diagnosis and treatment policy in 2013.²⁻⁴

Qinghai Province combined the implementation of a graded diagnosis and treatment system by strengthening medical insurance payment reforms. They pioneered the exploration and implementation of graded diagnosis and treatment systems in China.⁵ More than 30 medical consortia were established to promote division of labor and cooperation among medical institutions at all levels in Beijing in 2013, and preliminary results were achieved. Gansu Province fully implemented the graded diagnosis and treatment system in 2015. The province used medical treatment, medical insurance, price, and other means to guide patients to seek local medical treatment. In 2017, the Health Commission of Gansu province issued the supplementary opinions further to improve the construction of graded diagnosis and treatment system. In particular, 150 diseases were selected and determined as the classified diagnosis and treatment diseases of municipal-level hospitals.^{6,7} Gansu is a typical economically underdeveloped region in western China. As inequality between regions is still apparent, resources are mainly concentrated in economically developed

cities. Therefore, the number of patients in municipal-level hospitals increased rapidly in the short-term following policy implementation. As municipal-level hospitals undertake more obligations than their national and regional counterparts, further improvements in service quality and operational efficiency can only increase pressure.

Hospital services and scales have been a top research priority in recent years. This research allocation affects the health level of residents and plays an important role in the sustainable development of medical and health services.⁸⁻¹⁶ Similarly, research on the factors affecting hospital efficiency and improvement strategies has become the focus of analysis and discussion. It encourages hospitals to continue to work towards operational efficiency. Hence, effective performance evaluation has positive benefits for hospitals and can promote their development. There are many ways to evaluate performance using varied mathematical models. Sherman revealed that the most commonly used methods for assessing efficiency are as follows: ratio analysis, balanced score card (BSC), total factor productivity (TFP), regression analysis, production frontier approach (PFA), and data envelopment analysis (DEA).¹⁷ Ratio analysis can only evaluate a single input and output factor, whereas BSC, TFP, and PFA are suitable for problems involving multiple inputs and a single output. DEA can simultaneously evaluate multiple input and output factors, making it more suitable for applications in complex medical institutions and the healthcare industry environments.¹⁸⁻²¹

In recently studies, Zheng²² applied the non-parametric four-stage data envelopment analysis method (four-stage DEA) to measure the relative efficiencies of Chinese public hospitals from 2010 to 2016 and determine how efficiencies were affected by eight factors. Ibrahim²³ evaluated the efficiency of healthcare system in Lebanon from 2000 to 2015 by applying a modified data envelopment analysis (DEA) model. Chen¹² offered a comprehensive assessment of the efficiency of public hospitals operating in China's 31 regions. Based on a three-stage data envelopment analysis procedure, they assessed

the impact of the third-round health system reform in 2009. Therefore, there is research value in hospital efficiency evaluation after specific policy implementation to provide data for hospital administrators to optimize resource allocation.

Hospital efficiency is an important indicator for hospitals and has significant continuous research value. As a typical Chinese province with unbalanced medical resource development, Gansu province has particular research significance after implementing the hierarchical medical treatment policy. The services and scale of municipal-level hospitals in Gansu Province need to be further evaluated after implementing the graded diagnosis and treatment policy because of the increase in inpatients. Meanwhile, traditional Chinese medicine (TCM) hospitals are the primary health service providers of TCM, and their development is more unbalanced than other hospitals at the same level. With the vigorous growth of TCM in China, research on the efficiency of TCM hospitals is of great significance.²⁴ According to literature reviews, the efficiency study of municipal-level TCM hospitals in China after policy implementation was severely lacking. This paper aims to evaluate the efficiency of municipal-level TCM hospitals by DEA after a hierarchical medical treatment policy was implemented. We propose solutions to the problems existing in hospital operations, improve the productivity of medical resources, and promote the utilization efficiency of medical resources in those hospitals. The results of this study may also provide a reference for the sustainable development of public health in various countries.

Materials and Methods

Classification of Public TCM Institutions

Public TCM institutions with fewer than 100 beds in China generally referred to community health service centers. Institutions with 100-500 beds were set as secondary hospitals, while tertiary hospitals were institutions with more than 500 beds.

The Data Source

In this study, we used data from the monitoring and direct reporting systems of a traditional Chinese medical service network. The data consisted of the hospitals' basic facility information, financial statements, medical personnel, quantity of medical services reported by the hospitals, and quality control by National Administration of Traditional Chinese Medicine (NATCM), China. The sample included all municipal-level TCM hospitals of Gansu province from 2017 to 2019, including 13 secondary hospitals and five tertiary hospitals.

Methodology of DEA

DEA is a nonparametric method that evaluates the performance of mathematical planning models, including the relative efficiency of decision-making units (DMUs), using multiple input and output indicators.^{25,26} DEA has two

models—one is the Charnes, Cooper, and Rhodes model (CCR),²⁷ the other is the Banker, Charnes, and Cooper (BCC) model.²⁸ CCR assumes that production is a constant return to scale (CRS), meaning that any increase in input proportionally increases the output level.²⁹ BCC assumes that production involves variable returns to scale (VRS).³⁰ The health services production process is not linear, and the VRS technical efficiency assumption may be more appropriate.^{31,32} The CCR and BCC models can both be divided into the “input” and “output” orientations.¹³ The input-oriented model aims to reduce inputs, which is inconsistent with the current context of insufficient health resource investment in hospitals; therefore, the output-oriented model is adopted in this study.^{14,33}

In the output-oriented BCC-DEA model, there are k independent DMUs, each producing m outputs $Y(=[Y_1, \dots, Y_k])$ by using n inputs $X(=[X_1, \dots, X_k])$. Technical efficiency (TE) can be divided into pure technical efficiency (PTE) and scale efficiency (SE). Equation (1) was used to calculate the TE. If TE is equal to 1, the DMU is scale-efficient; if TE is less than 1, the DMU is inefficient.³⁴

$$TE = PTE \times SE \quad (1)$$

Selection Input and Output Indicators of the DEA Model

The selection of variables was guided by a literature review on efficiency analysis and by considering the availability of the relevant data,³⁵⁻³⁸ which include three broad categories: labor, capital, and supplies.³⁹ In this study, the staff number,^{19,40-42} total hospital beds,^{19,41,42} and the hospital areas^{43,44} were selected as input variables based on the abovementioned literature reviews. The number of outpatients and inpatients⁴⁵⁻⁴⁷ and total revenue^{14,48} were selected as output variables.

Analytical Tool

The database was established with Excel, and SPSS 19.0 was used for statistical analysis. Descriptive statistics and Correlation analysis were performed on the input and output variables. The Mann-Whitney test was used to compare the difference in input-output variables between TE-efficient and TE-inefficient hospitals. The DEAP 2.1 was used for DEA to evaluate the efficiency of 18 municipal TCM hospitals.

Results

Descriptive Statistics and Correlation Analysis

The descriptive statistics and correlation analyses are shown in Table 1. By 2019, the secondary hospital had 3,196 employees, 3,604 beds, 22,085.14 m² the total area, 587.37 million yuan total revenue, 1,620.88 thousand outpatients and 89,498 inpatients. This was an increase of 25.88%, 16.52%, 43.43%, 50.46%, 40.00% and 26.86% respectively compared

Table 1. Descriptive statistics of input and output variables (2017-2019).

	Year	Inputs					
		Staff		Beds		Area (m ²)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Secondary hospital	2017	195.31	106.57	237.92	132.64	11845.03	10357.38
	2018	250.77	134.82	272.38	165.65	15285.85	11099.61
	2019	245.85	138.14	277.23	167.16	16988.78	11309.79
Tertiary hospital	2017	554.80	411.12	655.80	233.17	32740.00	17783.49
	2018	573.00	416.91	667.80	247.38	36521.43	12911.96
	2019	732.20	317.19	653.80	272.24	37860.00	9305.63

	Year	Outputs					
		Total revenue (Million Yuan)		Output (Thousand)		Inpat	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Secondary hospital	2017	30.03	18.47	89.06	59.42	5426.85	3054.09
	2018	39.34	22.07	102.11	68.23	6486.31	4896.04
	2019	45.18	26.77	124.68	116.88	6884.46	4107.18
Tertiary hospital	2017	131.00	78.39	254.02	109.82	14337.80	6763.56
	2018	165.18	89.83	282.61	116.75	17224.80	8010.52
	2019	184.61	100.39	335.44	103.13	18595.40	9261.68

Note: S.D.: standard deviation; growth rate: Compared with the previous year; Output: Outpatients; Inpat: Inpatients.

Table 2. Correlation analysis of variables (2017-2019).

Variables	Inputs			Outputs		
	Staff	Beds	Area (m ²)	Total revenue (Million Yuan)	Output (Thousand)	Inpat
Inputs						
Staff	1.000	0.829*	0.707*	0.772*	0.678*	0.837*
Beds	0.829*	1.000	0.803*	0.840*	0.761*	0.909*
Area (m ²)	0.707*	0.803*	1.000	0.762	0.619*	0.739*
Outputs						
Total revenue (Million Yuan)	0.772*	0.840*	0.762*	1.000	0.896*	0.910*
Output (Thousand)	0.678*	0.761*	0.619*	0.896*	1.000	0.874*
Inpat	0.837*	0.909*	0.739*	0.910*	0.874*	1.000

Note: *means $P < 0.01$; Output: Outpatients; Inpat: Inpatients. The data didn't pass normality test ($P < 0.05$) and homogeneity test of variance ($P < 0.05$), so spearman correlation analysis was used. The background color part represents the symmetrical correlation index.

with 2017 statistics. The tertiary hospital had 3,661 employees, 3,269 beds, 189,300.02 m² total area, 923.04 million yuan total revenue, 1,677.19 thousand outpatients and 92,977 inpatients. This was an increase of 31.98%, -0.30%, 15.64%, 40.92%, 32.05% and 29.69% respectively compared with 2017 statistics. The increase in the number of staff in secondary hospitals was lower than that in tertiary hospitals; however, the increase in the number of beds was much higher than that in tertiary hospitals. The growth rates of the other items were the same as that in tertiary hospitals.

In this study, the input and output variables are relatively independent variables. The correlation coefficients of the input and output variables were analyzed (Table 2) and were strongly positively correlated ($P < 0.01$). The high correlation between inputs and outputs is evident, which meets the

isotonic property that the output does not decrease with the increase of input.⁹ The correlation coefficient of input-output indicators is between 0.615 and 0.910.

Result of the DEA Model

Operational efficiency of the municipal-level TCM hospitals. HS1-HS13 was used to represent 13 municipal-level secondary TCM hospitals, and HT1-HT5 represented 5 municipal-level tertiary TCM hospitals. DEA-BCC was conducted for the two data groups, and the results are presented in Table 3.

Among the secondary hospitals seen in Table 3, five hospitals (38.46%) achieved DEA efficiency, three (23.08%) were weak DEA efficient, and five (38.46%) were inefficient. In tertiary hospitals, three hospitals (40.00%) reached DEA

Table 3. The relative efficiency value of data envelopment analysis.

Hospital Level	DMUs	TE	PTE	SE	RS	Relative validity
Secondary hospital	HS1	0.836	0.860	0.972	drs	Invalidity
	HS2				const	Validity
	HS3	0.271	0.335	0.811	irs	Invalidity
	HS4	0.713	0.737	0.967	irs	Invalidity
	HS5				const	Validity
	HS6	0.626	0.898	0.696	drs	Invalidity
	HS7	0.602	0.707	0.851	drs	Invalidity
	HS8	0.906		0.906	drs	Weak validity
	HS9				const	Validity
	HS10	0.898		0.898	drs	Weak validity
	HS11				const	Validity
	HS12	0.706		0.706	irs	Weak validity
	HS13				const	Validity
Tertiary hospital	HT1	0.795		0.795	drs	Weak validity
	HT2				const	Validity
	HT3				const	Validity
	HT4	0.973		0.973	drs	Weak validity
	HT5	0.573	0.632	0.908	drs	Invalidity

Note: DUMs:Decision making units; TE: Technical efficiency; PTE: Pure technical efficiency; SE: Scale efficiency; RS: Return to scale; irs: Increasing; drs: Decreasing; const: constant.

Table 4. The data envelopment analysis average efficiency value with different level of hospitals.

Hospital Level	Year	TE (P=0.110)		PTE (P=0.043*)		SE(P=0.102)	
Secondary hospital N = 13×3(DMUs)	2017	\bar{x} 0	0.812	\bar{x} 0	0.887	\bar{x} 0	0.908
	2018	.812	0.804	.887	0.847	.908	0.944
	2019		0.868		0.909		0.948
Tertiary hospital N = 5×3(DMUs)	2017	\bar{x} 0	0.868	\bar{x} 0	0.926	\bar{x} 0	0.935
	2018	.868	0.913	.926	0.923	.935	0.988
	2019		1.000		1.000		1.000
Mean of all		\bar{x} =0.828		\bar{x} =0.898		\bar{x} =0.916	

Note: DMUs: Decision making units; TE: Technical efficiency; PTE: Pure technical efficiency; SE: Scale efficiency. p: P-value; *:P<0.05; \bar{x} : means value.

efficiency, while two (40.00%) were weak DEA efficient, and one (20.00%) was inefficient. Meanwhile, the TE value of DEA-inefficient hospitals in tertiary hospitals was greater than 0.9, indicating a marginal invalid state. The DEA efficiency of Level 3 hospitals was essentially the same as Level 2 hospitals.

Seven hospitals (HS2, HS5, HS9, HS11, HS13, HT2 and HT3) were DEA efficient, and the return to scale were constant, implying that the development of these hospitals had entered a stable period. As long as the dynamic balance of input and output was maintained, the stable development of hospitals could be guaranteed. The DEA results of five hospitals (HS8, HS10, HS12, HT1, and HT4) were weakly efficient, and their PTE was efficient. Still, SE was inefficient, indicating that the hospitals' health service and medical technology levels were compatible. Four hospitals (HS8,

HS10, HT1, and HT4) had decreasing SE, and one (HS12) had increasing SE. The overall operation scale was too large or too small, resulting in weak DEA efficient. Still, all inputs should be reduced or expanded equally to change the scale efficiency from weak efficient to efficient in order to achieve DEA efficiency. Six hospitals (HS1, HS3, HS4, HS6, HS7, and HT5) were DEA inefficient, with no economies of scale. Among them, the return on scale of two hospitals (HS3 and HS4) increased, whereas the return on scale of four hospitals (HS1, HS6, HS7, and HT5) decreased. In secondary hospitals, the lowest TE and PTE were observed in HS3 (0.271, 0.335), and the lowest SE was observed in HS6 (0.696). Among tertiary hospitals, the lowest TE was HT5 (0.573). The PTE of all tertiary hospitals were efficient except HT5 (0.632), and the lowest SE was in HT1 (0.795).

From 2017 to 2019, the average value of TE, PTE and SE in secondary hospitals was 0.812, 0.887 and 0.908, respectively. In tertiary hospitals, the average TE, PTE and SE was 0.868, 0.926 and 0.935 respectively (Table 4). TE, PTE and SE in secondary hospitals increased by 6.90%, 2.48% and 4.41%, respectively, and TE, PTE and SE in tertiary hospitals increased by 15.21%, 7.99% and 6.95%, respectively. The growth rate of tertiary hospitals was significantly faster than that of secondary hospitals. Comparing the efficiency values of different hospital levels, the difference of PTE was statistically significant (P<0.05), and there was no significant difference in the other two items (P>0.05).

The impact of TE validity on inputs and outputs. The 18 hospitals were divided into two groups according to whether TE was efficient, and Manny-Whitney test was conducted, as shown in Table 5. There was a statistically significant difference in

Table 5. The impact of data envelopment analysis validity on inputs and outputs ($\bar{x} \pm s$).

Hospital Level	Variables	TE Validity	TE Invalidity	P
Secondary hospital N = 13 × 3(DMUs)	N of DMUs	17	22	—
	Staff	203.47±118.40	251.64±131.18	0.200
	Beds	220.00±144.38	295.36±154.25	0.154
	Area (m ²)	10678.02±8568.79	17819.51±11578.52	0.045*
	Total revenue (Million Yuan)	38.81±22.93	37.70±23.54	0.967
	Output (Thousand)	126.62±104.28	88.80±62.83	0.163
	Inpat	6510.88±4514.28	6076.55±3709.06	0.944
Tertiary hospital N = 5 × 3(DMUs)	N of DMUs	10	5	—
	Staff	585.80±314.23	688.40±486.12	0.953
	Beds	612.60±231.01	752.20±231.32	0.310
	Area (m ²)	31884.50±12495.09	43352.43±11238.90	0.129
	Total revenue (Million Yuan)	165.40±82.22	149.99±103.56	0.768
	Output (Thousand)	323.26±101.28	225.54±97.73	0.049*
	Inpat	16892.30±6989.52	16373.40±9866.96	0.679

Note: DMUs: Decision making units; TE: Technical efficiency; Output: Outpatients; Inpat: Inpatients; p: P-value; *:P<0.05; \bar{x} : mean value; s: standard deviation value.

total area of hospitals between the TE efficient group and TE inefficient group ($P<0.05$) in secondary hospitals. The other variables were not statistically significant ($P>0.05$) in secondary hospitals. There were no statistical differences in the variables between TE validity group and TE invalidity group in tertiary hospitals ($P>0.05$), except for the total number of outpatients ($P<0.05$).

Discussion

In this study, a comparative analysis of municipal-level TCM hospitals efficiency in post-reform revealed the efficiency of an implementing graded diagnosis and treatment policy in Gansu Province. Indeed, significant progress has been made in medical and health services of municipal TCM hospitals in Gansu Province. The results confirmed that all medical institution resources, such as the number of personnel, number of beds, hospital area, hospital income, and number of out and inpatients in secondary or tertiary municipal-level TCM hospitals, showed an upward trend, consistent with other studies.^{22,49} Due to the different functional positioning and numbers of secondary and tertiary hospitals in Gansu province, the impact of policy implementation on them will be more or less different. The number of beds and hospital area growth of tertiary hospitals were lower than those of secondary hospitals from 2017 to 2019, which may be related to more support of the graded diagnosis and treatment policy to low-grade hospitals.^{9,49} Given the results, managers of secondary hospitals should pay more attention to adopting the corresponding policies and measures which could improve efficiency compared to tertiary hospitals.

In addition, five (38.46%) secondary hospitals and three (23.08%) tertiary hospitals achieved DEA efficiency, whereas the remaining 10 hospitals were DEA inefficient. These results are consistent with a study conducted in Ghana

that found 24% of hospitals were VRS technically efficient.⁵⁰ Another study conducted in China found that 71.4% of the urban hospitals in Guangxi were relatively inefficient.⁵¹ Tertiary hospitals have a higher level of development than secondary hospitals, consistent with the results of a study in Taiwan.¹³ Although Gansu Province has issued a series of graded diagnosis and treatment policies to support primary medical institutions and encourage medical personnel to work in primary level hospitals in recent years, there is still a trend of the slow development of basic hospitals.^{9,49} However, owing to poor conditions, low wages and poor development prospects of primary-level hospitals, medical personnel are reluctant to work in basic hospitals and prefer to go to high-level hospitals. For example, the minimum TE value in one secondary hospital was 0.273, the PTE value in this hospital was 0.355 and SE value was 0.811, indicating that the scale level of this hospital was good; The low efficiency was caused by the outdated technology. This hospital was located in ethnic minority area. The hospital's overall efficiency was low because of economic backwardness, lack of medical personnel, severely inefficient technical level, and health resource waste. As an economically underdeveloped area, Gansu's medical technology development lags behind economically developed areas. There are significant differences in economic and medical levels among different regions of the province due to different geographical locations. Second, the national policy of emphasizing western medicine and neglecting TCM has led to a deterioration in the development of TCM hospitals in Gansu Province. The state has recently emphasized the importance of developing and using TCM. As the main provider of TCM, TCM hospitals should use this opportunity to promote the efficient development of hospitals. This can be done by improving management efficiency, optimizing hospital operation scale, improving medical resource utilization efficiency,³⁷ and

completely converting the existing medical resource input into output.

Comparing DEA scores with other regions in China and other countries can explain the development of medical and health resources in different regions to some extent. According to above results, the average of TE scores was 0.828, the average of PTE scores was 0.898, and the average of SE scores was 0.916 for the municipal TCM hospitals in Gansu Province from 2017 to 2019. These showed increasing trends, indicating that the implementation of graded diagnosis and treatment policy have played a significant role in improving the relative efficiencies of public hospitals. This demonstrates the feasibility and effectiveness of the public hospital reform policy.²² However, the TE values of municipal TCM hospitals in Gansu Province were lower than those of other provinces. For example, from 2010 to 2014, the average TE values of public hospitals in Xinjiang were 1.000, 0.852, 0.953, 0.973 and 1.000, respectively; the average pure technical efficiency values were 1.000, 0.883, 0.970, 0.974 and 1.000, respectively; and the average SE values were 1.000, 0.966, 0.982, 0.999 and 1.000 respectively.⁵² In 2012, the average TE, PTE and SE values of public hospitals in Tianjin were 0.893, 0.909 and 0.979, respectively.⁵³ The mean TE scores for Gansu Province are still higher than those for the Spanish region of Extremadura (0.833),⁵⁴ South Korea (0.886), Oman (0.692) and all of China (0.806).⁵⁵ The difference in PTE between secondary hospitals and tertiary hospitals was statistically significant. It can be considered that the difference in efficiency between secondary hospitals and tertiary hospitals mainly came from the difference in the management level of hospital managers and the technical level of doctors. Over the three years, the personnel growth rate of secondary hospitals (25.88%) was less than that of tertiary hospitals (31.98%). There are three main reasons for this result as follows. First, Gansu is located in the northwest of China, which has a relatively backward economy, inconvenient transportation and few training opportunities. Second, the diseases of graded diagnosis and treatment are mainly diseases treated by western medicine. There are few diseases treated by traditional Chinese medicine, which affects the total number of patients in the TCM hospital and reduces the opportunities for doctors to practice. Finally, Gansu has a large area and small population. Its population density is much lower than the economically developed areas of China, so the demand for health services declines. The technical difference is the difference of technological proficiency of medical personnel, and the technical progress of medical personnel comes from continuous practice and training. First, we should increase the opportunities for medical personnel to study in economically developed areas to develop their proficiency. Second, the graded diagnosis and treatment policy should increase the number of medical items and characteristic diseases treated by TCM. Third, the government should develop a regional economy, improve living standards, and pay more attention to personal health. Finally, hospitals

can make full use of medical resources, improve the proficiency of medical staff, and enable operational efficiency.

There was a statistically significant difference in the total hospital area between the TE efficient and inefficient groups ($P < 0.05$). It can be considered that the hospital area of TE-efficient group was larger than that of TE-inefficient group in secondary hospitals. As China's policy is that the land belongs to the state, it is difficult for TE-inefficient hospitals to achieve TE efficient by increasing area investment. Other inputs can only be reduced in equal proportion to achieve TE validity. There was a statistically significant difference in the number of outpatient visits to tertiary hospitals ($P < 0.05$). Since China's current medical insurance policy reimburses hospitalization expenses more than outpatient expenses, many patients who could have been treated in outpatient care prefer hospitalization. This wastes limited medical resources, increases doctors' work burden, and can result in inefficient hospital outputs.¹⁹ Outpatient medical resources were not effectively utilized, while the inpatient medical resources were overloaded, resulting in scale efficiency (SE) inefficient of all medical resources in the hospitals. The government departments should reform the existing medical insurance policy, balance the proportion of outpatient reimbursement and inpatient reimbursement, and adopt the combination of single disease reimbursement and reimbursement according to the proportion of medical expenses.

Furthermore, the graded diagnosis and treatment policy should be divided into two types: diseases treated in outpatient and diseases treated in inpatient, and moderately control the hospitalization rate of outpatient patients. The relevant policy and measures could allow the outpatient and inpatient hospital resources to be fully utilized to improve the overall scale and efficiency of medical resources and achieve efficiency. Furthermore, the above advices and measures could effectively control the growth of medical expenses to reduce the financial burden on the government, the work burden on hospitals, and the disease burden on patients.

Conclusion

To date, no previous studies have examined the efficiency of municipal-level TCM hospitals after implementing a hierarchical medical treatment policy. Efficiency evaluation is an important part of the new medical reform and is necessary to solve the problem of limited and unbalanced medical resources.²² Based on municipal TCM hospitals in Gansu Province panel data from 2017 to 2019, this study measured the TE, PTE and SE of municipal TCM hospitals by using the DEA-BCC model index. Furthermore, the differences of variables between TE efficient group and TE inefficient group were studied to find out the factors that affect TE efficient. From 2017 to 2019, the total amount of health resources in municipal TCM hospitals in Gansu Province increased

steadily, and the overall equity of health care resource allocation was good. The validity of inputs and outputs of basic medical resources was more efficient in 2019 than in 2017. However, there were still great differences in regions between the TCM hospitals of Gansu Province.

Improving efficiency may be the best way to reduce hospital costs.³⁶ By 2019, all tertiary hospitals had achieved effective utilization of medical resources, which is efficient in DEA. However, six secondary hospitals (46.15%) are still in a weak efficient or inefficient state, so the inputs of health resources have not been fully utilized. Going forward, the government should address the problem of health resource utilization and strive to narrow the gap in the utilization efficiency of medical resources in different regions.⁵⁶

The graded diagnosis and treatment policy of Gansu Province are similar to the other parts of China, but there are great regional differences in health resources in Gansu Province and other Provinces.^{57,58} With the deepening of the graded diagnosis and treatment policy, the number of outpatients and inpatients in municipal hospitals will continue to increase over the next few years. Hospitals face an urgent need for transformation, development and efficiency improvement. In addition to supporting corresponding hardware facilities, hospital administrators should improve the working conditions of medical personnel, hire high-level medical personnel, pay attention to the introduction and training of professional and technical staff,⁵⁹ and improve management ability. These measures will improve technological capability and management ability.

Furthermore, this study suggests that the indicators and variables of other hospitals in Gansu Province should be extended according to different periods of graded diagnosis and treatment policy to further investigate the differences and determinants of TCM efficiency in hospitals in Gansu Province. Further research on TCM hospitals in other regions is needed to better understand the efficiency of TCM hospitals in China.

Limitations

This study has several limitations. First, hospitals were only evaluated over three years. Eighteen municipal TCM hospitals were evaluated after implementing the graded diagnosis and treatment policy. This reduced the stability and robustness of the evaluation results to some extent, and the study design still needs to be optimized. Second, the efficiency of municipal TCM hospitals may be affected by environmental factors, such as population composition, e.g., populations above the age of 65 or under the age of 15, local economic level, and health service cost. Finally, the selected variables may not be perfect, as the staff was not subdivided into doctors, nurses, and other personnel. However, despite its limitations, this study can be considered a useful preliminary

study to explore the efficiency of municipal-level TCM hospitals using DEA.

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Author Contributions

Yuanyuan Li and Xixin Niu drafted the first version of the manuscript.

Wei Zhou and Jun Tian collected, processed and normalized the data. Yuanyuan Li and Xixin Niu analyzed the data and interpreting the data.

Yuanyuan Li and Yongqiang Zhao revised the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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ORCID iD

Yuanyuan Li  <https://orcid.org/0000-0002-5179-7983>

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