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An Empirical Study on the Performance Evaluation of Introducing Artificial Intelligence Medical Service System into Medical Ecological Environment

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Abstract

Under the advance of time, development of science and technology, and popularity of network, the combination of medical ecological environment and information & communication technology provides diverse medical care services for the public. Having the elderly receive diverse medical services in neighboring communities, under constantly increasing medical expenses becomes the common objective of various countries. An artificial intelligence medical service system might be the ideal tool to actualize local aging. Taking prefecture-level cities in Shanghai as samples, total 16 DMUs are studied. With the operation of Modified Delphi Method, the geometric mean is used as the consensus of experts' input/output evaluation; and, DEA is applied to evaluate the performance on the introduction of artificial intelligence medical service system into medical ecological environment. The research results conclude that one DMU presents strong efficiency on the introduction of artificial intelligence medical service system into medical ecological environment, 6 DMUs reveal the efficiency in 0.9-1, and 9 DMUs appear the efficiency lower than 0.9. Slack Variable Analysis is further applied to improve excess and short inputs of prefecture-level cities. According to the results, suggestions are proposed, expecting that medical staff could real-time grasp the physiological state and offer timely assistance to reduce medical costs, promote the quality of life of people in communities, and improve doctor-patient interactive relationship.

Keywords: medical ecological environment, artificial intelligence medical service system, performance evaluation, medical service

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INTRODUCTION

National physical health is considered as the prerequisite to cultivate effective manpower for enhancing the economic efficiency and productivity of the society. In other words, national physical health is the key factor in the advance of a nation and the promotion of overall competitiveness. Sound medical-care service system network is the powerful backing of national health. In order to ensure national health, contemporary medical ecological environment has made effort to construct flexible and efficiency medical service systems to enhance national productivity, boom the economy, and strengthen national power. A medical service system covers levels of supply and demand to cope with the evolution of medical ecological environment that the concept is obviously adjusted. Especially, after being made public of network technology, the supply and demand for medical service could closely communicate through convenient channels to enhance the efficacy and reduce the waste of medical resources. Medical ecological environment is facing the change of external environment that the management strategy should be changed to conform to patients' real needs. Medical institutions therefore have to promote service quality, understand patients' real needs, and create attractive needs to ensure the sustained-yield management. The definition of medical service satisfaction should conform to patients' perception to be the real service.

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The decrease in birth rate and the extension of national life expectancy change the population structure and the obvious ageing in medical ecological environment. Increasing aged population enhances the public demands for health care. On the other hand, with the advance of time, the development of technology, and the popularity of network, the combination of medical ecological environment and information & communication technology could provide diverse medical care service for the public. The elderly care policies in various countries are gradually changed from concentrated medical service into local aging for the elderly naturally ageing in the familiar living environment with safe living environment, independent life and participation in social activity. In this case, the elderly could maintain the autonomy and self-esteem and present the quality of private life. Moreover, by combining local resources, community medical service network could be constructed to enhance the cost effectiveness of long-term medical care service to achieve the objectives of healthy aging and successful aging. It therefore becomes the common objective of various countries to provide the elderly with diverse medical service in neighboring communities under the increasing medical expenses. An artificial intelligence medical service system might be the ideal tool to actualize local aging. Aiming at the introduction of artificial intelligence medical service system into medical ecological environment, the performance is evaluated in this study, expecting that medical staff could real-time grasp the physiological state and timely offer assistance to reduce successive medical costs, enhance the quality of life of community people, and improve doctor-patient interactive relationship.

LITERATURE REVIEW

Medical Service

Hsu et al. (2017) indicated that economic commodity contained tangible items/goods and intangible labor/service. Although medical-care service was a part of intangible labor, the characteristics were different from tangible items for maintaining life or intangible labor. Han and Zhao (2002) mentioned that health care service specifically covered inquiry, auscultation, and examination in diagnosis, injection, administration of drug, topical application of drug (trauma drug), surgery, and rehabilitation in treatment, and tracking and verification in treatment situation judgment. Al-Jabri and Roztocki (2015) explained general health care service as health care service with direct or indirect purposes of treatment, correction, prevention of human diseases, injury, and health protection. LaMantia et al. (2016) stated that various health care services changed with time and space, advance of medical technology, and change in social value that they could not be covered with traditional ideas. Health care service therefore was not limited to disease diagnosis and treatment, but included prevention, health protection, and rehabilitation. Fredman et al. (2015) regarded medical service as a special professional business with highlighted uncertainties of incidence of disease and efficacy of treatment, compared to other businesses. Park and Blenkinsopp (2017) described that the former was the uncertainty of demands generated by consumers not being able to grasp the health conditions or know the time to get sick and the latter was the uncertainty of supply that patients and medical institutions could not know the treatment effect. Juhana et al. (2015) indicated that the uncertainty of getting sick induced consumers' demands for medical care service to highlight the irregularity and unpredictability, in comparison with the demand for other item/labor.

Telemedicine Service

Huang et al. (2017) explained that telemedicine was a term proposed in 1970s and meant remote treatment, revealing the use of information and communication technology to improve patients' treatment effect through medical treatment and medical information. Balkrishnan and Gaipov (2018) explained it as exchanging effective information with information and communication technology (ICT) for disease and injury diagnosis, treatment and prevention, research and evaluation, and health protection provided by health protection practitioners, where distance was a key factor and the promotion of individual and community health was the objective. Lee et al. (2017) defined it as correctly delivering the illness conditions and symptoms of cases to medical staff through electronic technology and communication so that medical staff could effectively confirm and supervise new illness conditions or change with information and communication equipment for immediate diagnosis and prescription treatment, health education intervention, supportive activity, and comorbidity prevention. Goren et al. (2016) told telemedicine from remote health protection that the former was limited to the service offered by physicians, while the latter was the service from general health practitioners, including nurses and pharmacists. Kim and Kim (2017) regarded telemedicine and remote health protection as exchanged synonyms. Telemedicine included four close elements of 1.aiming to provide clinical support, 2.intending to overcome geographic obstacles and connect users not at the same position, 3.involving in various types of information and communication technology, and 4.aimign to improve medical effect.

Artificial Intelligence Medical Service System

Chou and Chen (2016) explained that patients' physiological signals and security monitoring signals in the artificial intelligence medical service system were transmitted to the monitoring platform in the fixed workstation and handheld devices of medical staff and care staff through wireless network and even the medical logistics unit of pharmacy and operating room. The care staff preceded non-stop monitoring service and assist in the monitoring of medical staff's professional medical prescription. Tretteteig et al. (2017) indicated that it could precede real-time preparation and accelerate the administration process for medical behavior in emergency. Nunkoo et al. (2018) stated that an artificial intelligence medical service system could increase the data collection of patients' physiological changes through the long-term monitoring with diverse data to increase the research data for pathological analyses as well as exchange research data, under the secure mechanism of cloud data, to accelerate patients' inter-hospital data exchange and reinforce the balance and sharing of medical resources. Graham et al. (2017) indicated that family members could concern about patients' health and safety through the Internet; when there was abnormity, the system would automatically send information to the family members through the network transmission platform. The system was expected to actualize "ubiquitous medical" service and improve the quality and quantity of medical and health care. Kondasani and Panda (2015) described that an artificial intelligence medical service system, through new medical monitoring technology and equipment, could promote the integrity of medical monitoring data, enhance the quality and quantity of medical staff's judgment information, reduce costs for medical staff, and take information as the research data for the development of medical technology to further promote the quality of medical service (Song and Lee 2016).

Data Envelopment Analysis

Data Envelopment Analysis first appeared in the article announced by Charnes, Cooper, and Rhodes in 1978 (Stoica et al. 2015). Data Envelopment Analysis was a non-parametric method, i.e. calculating the points on the production boundary with the linear programming mathematical operation with multiple inputs and outputs of decision making units, without preset production function. Economically, the points on the production boundary referred to the most beneficial input/output combination for decision making units, i.e. relatively efficient units. The efficiency frontier composed of such efficient units was the so-called envelope. Furthermore, the relative efficiency of DMUs and the improvement direction for the achievement of efficiency could be measured by comparing the observation of input/output ratio with efficiency frontier.

According to the systematic Data Envelopment Analysis application induced by Chen et al. (2018), it contained the following four steps.

1. Definition and selection of decision making unit: Decision making units were the object evaluated with Data Envelopment Analysis. To have decision making units be evaluated at the same standpoint, DMUs should be confirmed the homogeneity, i.e. the same objective, executing similar work, and operating under the same market conditions. According to the empirical law proposed by An et al. (2015), the number of DMUs should be at least twice of the sum of the number of inputs and outputs.

2. Selection of input/output: Inputs/outputs were closely related to the relative efficiency of decision making units that the selection should consider the business characteristics of DMUs and confirm the organizational objectives. In regard to the selected inputs/outputs, the relevance of inputs/outputs should be tested, i.e. isotonicity between inputs and outputs, revealing that the quantity of outputs could not be decreased when the quantity of inputs is increased.

3. Selection of evaluation model: The selection of evaluation model should depend on the research objective and information required for decision making.

4. Analysis and explanation of result: The Data Envelopment Analysis results should be able to explain the performance of DMUs and provide suggestions for improvement as the decision-makers' reference of business improvement. In this case, the analysis results should cover efficiency analysis, Slack Variable Analysis, and suggestions for management.

RESEARCH DESIGN

DEA is applied in this study to evaluate the performance on the introduction of artificial intelligence medical service system into medical ecological environment, where proper inputs and outputs should be selected to effectively evaluate the system performance of DMUs. To combine the selection of inputs and outputs with expert opinions, reduce input costs, and avoid fuzziness in the survey process, Modified Delphi Method is applied to select the inputs and outputs. Total 50 copies of questionnaire are distributed for this study, and 37 valid copies are retrieved, with the retrieval rate 74%. Researchers indicated that the public opinions from more than 5 participants could be the analysis reference. The interviewed experts cover industry, government, and university and present frequent interaction in medical ecological environment that it shows certain representativeness.

After the operation with Modified Delphi Method, the geometric mean is regarded as the experts' consensus of input/output evaluation, and the median of the input/output evaluation scores is used as the selection standard for evaluating the performance on the introduction of artificial intelligence medical service system into medical ecological environment. Total 4 inputs/outputs and 16 DMUs strictly selected from prefecture-level cities in Shanghai are covered in this study.

All variable data used in this study are acquired from public prospectuses and annual reports.

Definition of variable:

Input Variable

(1) Introduction cost: referring to all input expenses for the introduction of artificial intelligence medical service system into medical ecological environment.

(2) Promotion cost: referring to all input expenses for promoting the use of artificial intelligence medical service systems.

Output Variable

(1) Promotion scale: referring to the number of medical units using artificial intelligence medical service systems.

(2) Market scale: referring to the number of people using artificial intelligence medical service systems.

Table 1. Relative efficiency of prefecture-level cities

prefecture-level city	overall efficiency	pure technical efficiency	scale efficiency
Huangpu District	0.91	0.92	0.91
Xuhui District	1.00	1.00	1.00
Changning District	0.88	0.87	0.88
Jing'an District	0.82	0.81	0.82
Putuo District	0.80	0.80	0.80
Hongkou District	0.96	0.96	0.96
Yangpu District	0.84	0.84	0.84
Minhang District	0.90	0.90	0.90
Baoshan District	0.78	0.78	0.77
Jiading District	0.75	0.74	0.75
Pudong New District	0.98	0.97	0.98
Jinshan District	0.92	0.92	0.91
Songjiang District	0.87	0.87	0.87
Qingpu District	0.91	0.91	0.90
Fengxian District	0.81	0.80	0.81
Chongming District	0.77	0.76	0.77

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Efficiency Analysis of Introducing Artificial Intelligence Medical Service System into Medical Ecological Environment

The DEA efficiency evaluation results could help understand the efficiency introducing artificial intelligence medical service system into medical ecological environment. Efficiency=1 stands for a DMU being relatively efficient; on the contrary, DMUs with the efficiency smaller than 1 are relatively inefficient. The empirical results, **Table 1**, show that 1 prefecture-level city is relative efficiency, with the efficiency=1, that the prefecture-level city achieves the ideal state in the introduction of artificial intelligence medical service system into medical ecological environment. The rest prefecture-level cities are relatively inefficient in the introduction of artificial intelligence medical service system into medical ecological environment.

Slack Variable Analysis

Regarding the analysis of returns to scale, **Table 2**, 1 prefecture-level city reveals constant returns to scale that the efficiency in introducing artificial intelligence medical service system into medical ecological environment achieves the optimal. The rest 15 prefecture-level cities appear increasing returns to scale that the scale could be expanded to enhance the marginal returns and further promote the efficiency.

In terms of Slack Variable Analysis, the improvement for prefecture-level cities with excess and short inputs is shown in **Table 2**. A prefecture-level city

Table 2. Relative efficiency of prefecture-level cities

decision making unit (DMU)	improvement of input		improvement of output		returns to scale
	introduction cost	promotion cost	operating revenue	market expansion	
Huangpu District	1	0	1	1	IRS
Xuhui District	0	0	0	1	IRS
Changning District	2	1	0	1	IRS
Jing'an District	0	2	2	2	IRS
Putuo District	0	2	3	2	CRS
Hongkou District	0	1	0	2	IRS
Yangpu District	1	1	2	0	IRS
Minhang District	0	1	1	1	IRS
Baoshan District	2	3	2	3	IRS
Jiading District	3	4	4	4	IRS
Pudong New District	0	0	1	1	IRS
Jinshan District	0	1	1	0	IRS
Songjiang District	1	1	2	0	IRS
Qingpu District	0	0	1	2	IRS
Fengxian District	2	2	0	3	IRS
Chongming District	0	1	3	2	IRS

Data source: self-organized in this study

could reach efficient introduction of artificial intelligence medical service system into medical ecological environment by reducing inputs on the items with excess inputs and increasing inputs on the items with short inputs.

CONCLUSION

Researchers further classified DMUs into strong efficiency, marginal efficiency, marginal inefficiency, and obvious inefficiency. Strong efficiency referred to the efficiency=1 and the slack variable=0, implying the intensity largely exceeding inefficient DMUs. Such a type of units could remain the efficiency unless there were major changes in the inputs and outputs. Marginal efficiency referred to the efficiency=1, but at least 1 slack variable≠0. Such a type of units would reduce the efficiency below 1 simply by increasing inputs or decreasing outputs. Marginal inefficiency, with the efficiency<1 but >0.9, could easily enhance the efficiency to 1. When the efficiency was small than 0.9, it was obvious inefficiency. Such a type of units would be difficult to become efficient in short period. A unit with the efficiency<0.75 would maintained the inefficiency unless there were major changes in inputs and outputs.

The efficiency acquired with DEA and the variable information, **Table 1**, reveal that 1 DMU, about 6% of all DMUs, shows strong efficiency, efficiency=1, on the introduction of artificial intelligence medical service system into medical ecological environment; 6 DMUs, about 38% of all DMUs, present the efficiency in 0.9-1, as marginal inefficiency, which could be more easily enhanced; 9 DMUs, about 56% of all DMUs, show obvious inefficiency, efficiency<0.9, among which Jiading District appears the lowest efficiency, 0.75, on the introduction of artificial intelligence medical service system into medical ecological environment.

SUGGESTION

According to the research analysis results, suggestions aiming at the introduction of artificial intelligence medical service system into medical ecological environment are proposed in this study.

1. Application of empirical medical reports to help patients make decision or self-judgment. For instance, patients would agree with the diagnosis and the optimal treatment of the diseases found on the Internet or Chinese Database with empirical medical remarks. People with regular health checks would acquire the reports, in which the inclusion of empirical medical remarks and individualized data analyses could be accepted in medical ecological environment. People would expect the received treatment being the best treatment. Similarly, the provision of individualized empirical medical remarks and health contents in the report acquired after seeing a doctor would be an effective medical service system.

2. In the database of an information system in medical ecological environment, the correlation among diseases acquired with the mining tool for medical ecological environment might appear several possible combinations. When an artificial intelligence medical service system is able to combine patients' examination data, the accurate disease combination of the patient would be acquired. In this case, it could effectively prevent diseases to achieve the effect of preventive medicine.

3. An artificial intelligence medical service system could provide institutions and patients in medical ecological environment with more interaction choices, with the benefits of promptness, convenience, interaction, and low costs. Medical behavior is divided into physical contact (e.g. palpation or surgery) and unnecessary physical contact. An artificial intelligence medical service system mainly provides non-physical

(virtual) contact. It is suggested that artificial intelligence could be applied to provide the functions of online simply medical inquiry, referral between same trade and cross-industry alliance, and creation of virtual group with mutual medical assistance.

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