A medical quality evaluation method based on combined weight

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Received 1 March 2014, www.cmnt.lv

Abstract

Medical quality evaluation is the key and important link of the current medical institutions improve the core competitiveness, considering the characteristics of the medical industry, the paper constructs the surgical and non-surgical medical quality evaluation index system. In addition, the traditional medical quality evaluation in determining the index weight coefficients are too single, it is easy to cause the subjective assessment results too much or the accuracy is not high. Therefore, the paper using the Analytic Hierarchy Process (AHP) for subjective weight and using the Rough Set (RS), then get them together and put forward an approach of medical quality evaluation method based on combined weight, this method absorbs the advantage of them and overcomes the disadvantages of them and achieve the complementary advantages. Finally through the case analysis, verifying the feasibility and effectiveness of the method.

Keywords: medical quality evaluation, indicator system, combined weight, AHP, RS

1 Introduction

With the development of medical and health services, the evaluation of medical quality has become one of the key of medical institutions improve the core competitiveness, the evaluation of medical quality not only can evaluate the medical quality of the medical institutions, also can objectively reflect the existing problems and the weak links in the medical institutions, then provide decisions for the managers of the medical institutions and further to help the medical institutions to change and improve the medical quality in some specific ways. Domestic experts in the field of medical management has carried on the exploration and research for a long time. According to different provinces and different levels of medical institutions, the corresponding evaluation indicator system is also different each other, but is gradually perfect. The medical management department of the centre and provinces has already taken all kinds of means and measures to evaluate the medical quality of the medical institutions. The current evaluation of medical quality mainly includes qualitative analysis and quantitative analysis. Qualitative analysis includes expert experience, scores of patient satisfaction and hospital grading system, etc. Only use qualitative analysis often cause subjective evaluation results. Single use qualitative analysis often cause subjective evaluation results; Quantitative analysis includes calculate indicator data, analyse the number of changes, etc. although depend on quantitative analysis can get objective evaluation results, but if the evaluative data is not real also lead to the deviation of results. Therefore, at present the main problems of medical quality evaluation is how to combine the subjective evaluation results and objective evaluation results and get a comprehensive evaluation results.

This paper basis for the indicator system of medical quality evaluation, combine the subjective weight based on analytic hierarchy process (AHP) and the objective weight based on rough set, then build the optimization model of the comprehensive weights. Finally, though the function of Lagrange verify the feasibility of the model.

2 Medical quality indicator system

The indicator of medical quality evaluation is a scientific concept which reflects the pros and cons of medical quality, on the basis of the statistics, getting different indicator together and building the indicator system of medical quality evaluation are the premises and prerequisites of the medical quality evaluation. In this paper, the acquisition of the indicator system of medical quality evaluation and the construction of indicator system, mainly from the following several aspects:

1) Reference 2005-2010, the ministry of health department completes <the establishment and application research of indicator system of China hospital medical quality evaluation>, it propose the Chinese Medical Quality Indicator System (CHQIS), the system set up the three categories of 11 1 level indicators and 33 2 level indicators which include the in-hospital death related, non-plans to return relevant, related adverse events. Currently CHQIS has 730 single indicators and 4610 composite indicators.

2) Consult and reference many documents which elated to the medical service quality evaluation at home and abroad, foreign medical quality evaluation develop earlier and the choice of many indicators are through strict

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screening and clinical trials that can reasonably reflect the medical quality, it has good scientific and sensitivity. Such as the International Quality Indicator Proiect [1, 2] (IQIP) that divided into 25 categories and 285 indicators, it used for evaluate all levels of hospital and medical institutions, etc. IQIP pays attention to the results of the medical service and patients interests; focus on the influence of "negative event"; stress on the comparability of indicators; the choice standard of indicators are more rigorous.

TABLE 1 Non-surgical medical service quality evaluation indicator system

Indicator classification	First indicator	Second indicator
Non-surgical	Therapeutic effect	Cure rate
		Improvement rate
		Not cured rate
		Death rate
	Work efficiency	Inpatient Amount
		3-day-correct-diagnosis rate
		Average length of stay
		The coincidence rate of Admission and Discharge
	Diagnostic level	The coincidence rate of clinic and pathology
		The coincidence rate of radiation and pathology
		Adverse reaction rate of blood transfusion
		Adverse reaction rate of transfusion
	Medical records writing	Medical record rate class a
		Medical record rate class b
		Medical record rate class c
	Cost	All-in cost

TABLE 2 Surgical medical service quality evaluation indicator system

Indicator classification	First indicator	Second indicator
Non-surgical	Therapeutic effect	Cure rate
		Improvement rate
		Not cured rate
		Death rate
		Healing rate class a
		Healing rate class b
		Healing rate class c
	Work efficiency	Inpatient Amount
		3-day-correct-diagnosis rate
		Average length of stay
		The coincidence rate of Admission and Discharge
	Diagnostic level	The coincidence rate of clinic and pathology
		The coincidence rate of radiation and pathology
		Adverse reaction rate of blood transfusion
		Adverse reaction rate of transfusion
		The coincidence rate of preoperative and postoperative
	Medical records writing	Medical record rate class a
		Medical record rate class b
		Medical record rate class c
	Cost	All-in cost

1) Quantitative analysis [3] based on medical data, while due to the large amount of data, data scattered, do not have a unified format, etc. Causing some data of indicators cannot acquire or the data quality cannot meet the conditions of evaluation, therefore in the process of the selection of indicators, we need to refer medical data, and then confirm the collection of the indicators.

2) Refer to some opinions and suggestions, which are given by relevant experts, these experts, are expert in the field of health care or medical management for a long time, they bear rich experience and provide authoritative evaluation indicators, these indicators can scientifically and reasonably reflect the medical quality.

Based on the research of the above several aspects and established the medical quality evaluation indicator system that direct at the surgical and non-surgical. Among them non-surgical categories including five primary indicator and 16 secondary indicator, surgery including 5 primary indicator and 20 secondary indicator (Table 1 and 2).

3 Confirm indicator weight

3.1 ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP) was first proposed by Thomas l. Saaty who is the famous American operations research expert and the professor at the university of Pittsburgh in the 1970 s [4]. AHP not only is a good subjective weighting method, but also a multi-criteria method of thinking. It makes the processes of people's thought hierarchical and quantitative [5, 6] and applies to the target complex and lacks the necessary data, meanwhile it brings us a problem-solving ideas that from the perspective of problem as a whole, by constructing a hierarchical structure, evaluating the influence of each part on the whole, so as to achieve the purpose of solving the problem.

The specific steps of calculate the subjective weight are as follows:

1) Establish hierarchical structure: the purpose of establishing hierarchical structure is to bring the complex issues organized and hierarchical, according to the target layer, criterion layer and measures layer construct the hierarchical model. The target layer only has one element, criterion layer can be divided into different levels and groups, the elements of different levels belong to the subordinate relation. Measures layer is located in the bottom of the hierarchy, the layer provides solutions to achieve objectives (elements) and has a plurality of measures.

2) Construct judgment matrix and assignment: after confirming the hierarchical structure, we need to compare between two indicator elements under the same layer that impact on the upper indicator elements at the criterion layer and construct judgment matrix, Thomas l. Saaty proposed the 1-9 scaling method to measure the importance between the two elements of two indicators, as shown in Table 3:

TABLE 3 Element 1-9 important degree

a_{ij}	Two indicators compared	Explain
1	Equal important	Indicator *i* and *j* equal important
3	Little important	Indicator *i* and *j* little important
5	More important	Indicator *i* and *j* more important
7	Obviously important	Indicator *i* and *j* obviously important
9	Absolutely important	Indicator *i* and *j* absolutely important
2, 4, 6, 8	Between two adjacent important degree	
The reciprocal of the above	Two goals in turn	

Judgment matrix $A=\left(a_{ij}\right)n\times n$, A meet the following properties: 1) $a_{ij}>0$; 2) $a_{ij}=1/a_{ji}$, $(i,j=1,2.....n)$; 3) $a_{ii}=1$.

1) Hierarchical single sorting and inspection: after determine all the matrixes, we need to sort each matrix, namely solving matrix eigenvector, thus obtained weight value of each indicator. Taking an example of matrix $B=\left(b_{ij}\right)n\times n$, the steps of calculate the weight vector are as follow:

a) For each column as normalized $B_{ij}=\dfrac{b_{ij}}{\sum_{i=1}^{n}b_{ij}}$, $(i=1,2.....n)$;

b) For the sum of each row by row $W_i=\sum_{i=1}^{n}B_{ij}$, $(i,j=1,2.....n)$;

c) For vector $W_i=(W_1,W_2....W_n)^t$ as normalized, get $w_i=(w_1,w_2....w_n)^t$ as the approximate solution of the characteristic vector for matrix, namely the weight coefficient of indicator. After get the weights of indicators, we need check consistency of judgment matrix and ensure the matrix bear transitivity and consistency.

The steps to check consistency are as follow:

a) Calculate the maximum eigenvalue of the judgment matrix $\lambda_{\max}=\sum_{i=1}^{n}\dfrac{(Bw)_i}{nw_i}$;

b) Calculate consistency indicator *C.I.*: $C.I.=\dfrac{\lambda_{\max}-n}{n-1}$;

c) Look-up table to determine the corresponding average random consistency indicator *R.I.*, according to different order of judgment matrix to check the table and get the average random consistency indicator *R.I.*, the average random consistency indicator *R.I.* as shown in Table 4:

TABLE 4 Average random consistency indicator *R.I.*

Matrix order	1	2	3	4	5	6	7	8
R.I.	0	0	0.52	0.89	1.12	1.26	1.36	1.41

d) Calculate and determine the consistency of proportion *C.R.*, $C.R.=\dfrac{C.I.}{R.I.}$. When *C.R.* < 0.1,the consistency of judgment matrix is acceptable, *C.R.* > 0.1, we consider the consistency of judgment matrix does not meet the requirements and need to re-amend the judgment matrix.

2) Hierarchical total sorting and inspection: In general, the sorting result of the last layer in the criterion layer, calculation and test steps are similar to the single sorting and inspection.

3.2 ROUGH SET THEORY

In 1982 Z. Pawlak formally proposed rough set theory [7], which is a new mathematical tool to analyse and deal with incomplete data and fuzzy knowledge representation. By using this incomplete and vague information, analysis and processing, we can find some hidden knowledge and useful information. Rough set theory has the advantage that in addition to data set, does not need require any preparative or additional information about the data, so the description of the uncertainty and processing are relatively objective [8].

Definition 1: A knowledge representation system $K=(U,Q,V,F)$, *U* is the domain, *Q* is a set of attributes, divided into condition attribute set *C* and decision attribute set *D*, $Q=C\bigcup D$, $C\bigcap D=\varnothing$, $V=\bigcup_{a\in A}V_a$ is a collection of property values, V_a represents a range of attributes $a\in Q$, f is $U\times A\rightarrow V$ mapping.

Definition 2: Given a domain *U*, $x,y\in U$, $P\subseteq Q$, if meet $\forall q\in P: f_q(x)=f_q(y)$, said object *x* and *y* to attribute set P is not identified. Denoted *Ind*(*P*), that is the intersection of all equivalence relations. Expressed as $Ind(P)=\{(x,y)\in U\times U\mid \forall p\in P, p(x)=p(y)\}$.

Definition 3: An information system $S=\left(U,A\right)$, meet object set $X\subseteq U$ and attribute set $R\subseteq A$. Under *U* certainly belongs to the set of all the objects that consists of a set *X* is called *X* lower approximation, expressed as $R\_(X)=\{x\in U\mid [x]_R\subseteq X\}$. Under *U* certainly or maybe belongs to the set of all the objects that consists of a set *X* is called *X* upper approximation, expressed as $R^-(X)=\{x\in U\mid [x]_R\cap X\neq\varnothing\}$. *R* is the positive domain of *X* $POS_R(X)=R\_(X)$; *R* is the negative domain of X $NEG_R(X)=U-R^-(X)$. The boundary of *X* $BN_R(X)=R^-(X)-R\_(X)$.

Definition 4: The information entropy *H*(*P*) of knowledge *P* is defined as $H(P)=-\sum_{i=1}^{n}p(X_i)\log(p(X_i))$.

Definition 5: the condition entropy $H(Q\mid P)$ of knowledge $Q(U/ind(Q))=\{Y_1,Y_2,...Y_m\}$ to knowledge $P(U/ind(P))=\{X_1,X_2,...X_m\}$ is defined as:

$$H(Q\,|\,P) = -\sum_{i=1}^{n} p(X_i)\sum_{j=1}^{m} p(Y_j\,|\,X_i)\log(p(Y_j\,|\,X_i)),$$

$$p(Y_j\,|\,X_i) = \frac{|\,Y_j \cap X_i\,|}{|\,X_i\,|},\ i = 1,2....n\,,\ j = 1,2....m\,.$$

Definition 6: $S = (U, R, V, f)$ is a decision making system, $C \cup D = R$, C is condition attribute, D is decision attribute, $A \subset C$, the importance of any attribute $x_i \in C - A,\ \ SGF(x_i, A, D)$ is defined as:

$$SGF(x_i, A, D) = H(D\,|\,A) - H(D\,|\,A \bigcup \{x_i\}),$$

the greater the value of *A*, the greater the importance of the attribute, namely the indicator weight coefficient is larger, on the contrary, the smaller the importance of attribute, the smaller the indicator weight coefficient.

3.3 COMBINATION WEIGHTING

Assuming a decision information system $K = (U, Q, V, F)$, the subjective weight coefficient $w_{ai} = (w_{a1}, w_{a2}....w_{an})^t\ (i = 1,2.....n)$ obtained by the AHP, the objective weight coefficient $w_{bj} = (w_{b1}, w_{b2}....w_{bn})^t\ (j = 1,2.....n)$ obtained by the RS, w_{ck} is the combination of both weight coefficient, w_{ai}, w_{bj}, w_{ck} meet the following conditions:

$$\begin{cases} \sum_{i=1}^{m} w_{ai} = \sum_{j=1}^{m} w_{bj} = \sum_{k=1}^{m} w_{ck} = 1, (i, j, k = 1,2.....n) \\ 0 \le w_{ai} \le 1 \\ 0 \le w_{bj} \le 1 \\ 0 \le w_{ck} \le 1 \end{cases}.$$

Establish an optimization model in the feasible region Ω:

$$\min\left\{ \sum_{i,j,k=1}^{m} [\mu(w_{ck}{}^2/2 + w_{ai}{}^2/2 - w_{ck} * w_{ai}) + (1-\mu)(w_{ck}{}^2/2 + w_{bj}{}^2/2 - w_{ck} * w_{bj})] \right\},$$

μ is experience factor, $0 \le \mu \le 1$, the feasible region Ω meet $\Omega = \{w_{ck} \,\big|\, \sum_{k=1}^{m} w_{ck} = 1, 0 \le w_{ck} \le 1, (k = 1,2.....n)\}$ and the optimization model has only one solution $w_{ck} = \mu w_{ai} + (1-\mu) w_{bj}$, $(i, j, k = 1,2.....n)$.

Proof: for the Lagrange function:

$$L(w_{ck}, \lambda) = \sum_{i,j,k=1}^{m} [\mu(w_{ck}{}^2/2 + w_{ai}{}^2/2 - w_{ck} * w_{ai}) + (1-\mu)(w_{ck}{}^2/2 + w_{bj}{}^2/2 - w_{ck} * w_{bj})] + \lambda\left(\left|\sum_{k=1}^{m} w_{ck} - 1\right|\right),$$

$$\frac{\delta L}{\delta w_{ck}} = 0\,,\ \sum_{k=1}^{m} w_{ck} - 1 = 0\,,$$

solve equations:

$$\begin{cases} \sum_{k=1}^{m} w_{ck} - 1 = 0 \\ \mu(w_{ck} - w_{ai}) + (1-\mu)(w_{ck} - w_{bj}) = 0 \end{cases},$$

get $w_{ck} = \mu w_{ai} + (1-\mu) w_{bj}$, $(i, j, k = 1,2.....n)$.

According to the above proof we can know that the combination empowerment not only overcomes the subjective factors of excessive reliance on experience, but also avoid the only rely on the objective factors of data, thus improve the accuracy of the evaluation results.

4 Example analysis

In order to verify the feasibility of the evaluation method, based on the HIS data in a hospital of Zhengzhou City, using the combined weight method to evaluate five doctors' medical quality in the diagnosis of coronary heart disease (non-surgical). Due to the indicator system is numerous, so we select cure rate (*A*), the coincidence rate of admission and discharge (*B*), medical record rate class a (*C*), average length of stay (*D*), all-in cost (*E*) as the evaluation indicators.

4.1 AHP CALCULATE SUBJECTIVE WEIGHT COEFFICIENT

First of all, establish hierarchical structure, $D_i (i = 1,2,3,4,5)$ represent five doctors shown in Figure 1.

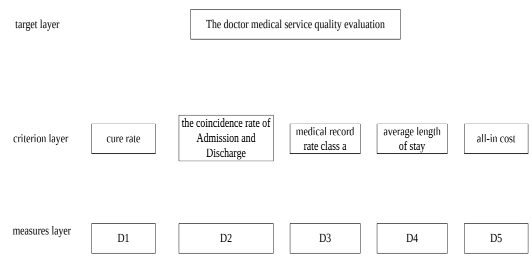

FIGURE 1 Hierarchical structure.

Then construct judgment matrix, as shown in Table 5:

TABLE 5 Judgment matrix

	A	B	C	D	E
A	1	5	7	4	3
B	1/5	1	3	1/4	1/5
C	1/7	1/3	1	1/5	1/6
D	1/4	4	5	1	1/3
E	1/3	5	6	3	1

Then calculate the weight vector, get the weight coefficient of indicator w_a = (0.4699, 0.0733, 0.0484, 0.1448, 0.2636). Finally check the consistency, when *n* = 5, *R.I.* = 1.12, the maximum eigenvalue $\lambda_{\max}$ = 5.2465, *C.R.* = 0.055 < 0.1, the matrix meets the requirement. We can be seen that the weight coefficient accounted for the largest, followed by the all-in cost, average length of stay, the coincidence rate of admission and discharge, and finally the smallest proportion of medical record rate class *a*.

4.2 RS CALCULATE OBJIECTIVE WEIGHT COEFFICENT

Firstly, normalize and discretize the initial sample data (Table 6), obtain evaluation data set and construct decision table (Table 7), regard the five evaluation indicators as the condition attributes, reference w_a as decision attribute (*F*).

TABLE 6 The initial sample data table

	A	B	C	D	E
D1	97.4%	96.1%	98.7%	26	2345
D2	90%	98%	100%	23	2468
D3	91.7%	93.3%	98.3%	5	2180
D4	78.8%	100%	92.9%	29	3216
D5	69.2%	84.6%	100%	35	3238

TABLE 7 Decision table

	A	B	C	D	E	F
D1	1	2	2	3	1	1
D2	1	1	1	2	2	2
D3	1	2	2	1	1	1
D4	2	1	3	3	3	3
D5	3	3	1	3	3	3

According to the definition by using the information entropy theory, solve the importance degree of condition attributes, the weight coefficient of indicator.

4.3 COMBINATION WEIGHT CALCULATE THE WEIGHT

After confirm the subjective weight coefficient w_a and objective weight coefficient w_b, generating into the Equation $w_{ck} = \mu w_{ai} + (1-\mu) w_{bj}$, $(i, j, k = 1, 2, ..., n)$. When tend to subjective experience, $\mu \in [0.5, 1]$; when tend to objective experience, $\mu \in [0, 0.5]$; here take μ = 0.38, make the subjective and objective weight coefficient ratio of the golden number. Calculated combination weight coefficient and the subjective and objective weight as shown in Table 8:

TABLE 8 Combination weight coefficient

	A	B	C	D	E
AHP	0.4699	0.0733	0.0484	0.1448	0.2636
Rough	0.2573	0.1394	0.1333	0.2444	0.2254
Combination weight	0.3381	0.1143	0.1010	0.2067	0.2399

As can be seen from the results, the combination weight and the subjective and objective weight basically have the same sorting, weight coefficient between the two weights, it make the result more accurate and reasonable. Finally, the combination of combination weight coefficient with sample data, to get the final rank of five doctors, D3 ranked the highest, followed by other D1, D2, D4, D5.

5 Conclusions

Against the disadvantages of the AHP and RS, this paper combines the two methods and discusses the application of combination weight in the medical quality evaluation. Through the example analysis, it proved that the method is feasible and improve the accuracy of the evaluation result to a certain extent and provide a new method for medical evaluation and research direction.

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