Study on the Application of System Structure Model in Layering Influencing Factors of Hypertension Disease

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Abstract

Based on the lack of clear etiological evidence of the influencing factors of hypertension and the appearance of symptoms in various forms, this paper studies the application of the system structure model to calculate the weight of the important influencing factors, determine main influencing factors and control the development of the disease with the possible influencing factors as well as important influencing factors obtained using rule extraction and Delphi method.

Keywords

System structure model, Hypertension, Influencing factors.

This paper, combined with the project "Demonstration and Application of Hypertension Prevalence Trend Analysis System Based on Regional Medical Big Data", which was specially developed by Shanghai Science and Technology Commission, is based on data collected from hypertension patients in Shanghai Ruijin Hospital and 34 medical association hospitals for nearly 10 years. The paper used the system structure model to establish the adjacent matrix that affects the formation of hypertension disease, calculated the reachable matrix, and obtained the hierarchical structure of the influencing factors, in order to calculate the weight of each influencing factor, determine the main influencing factors and control it effectively. This helps precaution crucial, early treatment, control hypertension, improve life quality, and promote the effective use of health resources.

1. Selection of Influencing Factors

Hypertensive diseases have a long onset of illness and lack of clear evidence of etiology. Once the disease progresses, it will not heal. Therefore, it is necessary to select the influencing factors that may induce hypertension. We sorted the data collected from more than 2 million outpatients and more than 10,000 hospitalized hypertensive patients stored in HIS systems of Shanghai Ruijin Hospital and 34 Medical Association Hospital Hypertension Departments in the past 10 years, excluded the missing and incomplete information, and used random methods to extract 210,000 patient cases as the basis for analysis and research. The extracted data were classified according to general data, blood pressure phenotype, antihypertensive drugs, metabolic status, target organ damage and coexisting clinical hypertension disorders. Their distribution were shown inTable 1.

Table 1. Outpatient and inpatient data of patients with hypertension

Case information	Patient Number	Condition Matched	Research Content
General information	50000	Datainclude:age, gender,smokinghistory,drinking history,family history,past history, medicationhistory, onset time, etc.	The variation of age and sex of hypertensive patients, and the proportion of smokers and drinkers in hypertensive patients.
Blood pressure phenotype	30000	Datainclude: clinical blood pressure, ambulatory blood pressure (the ambulatory blood pressure record per person contains at least 48 blood pressure readings and 48 heart rate readings);	1. The proportion of white coat hypertension, occult hypertension, morning hypertension, and nocturnal hypertension; 2. Compare the clinical blood pressure, ambulatory blood pressure, and cardiovascular and cerebrovascular events in the clinic; 3. The change in the rate of hypertension control;
Antihypertensive drug	100000	Data include: the prescription of antihypertensive drugs in the discharge abstract of hospitalized patients, and the antihypertensive drugs prescribed by the outpatients each time;	Change of medications taken by patients with hypertension; variation in the combination regimen;
Metabolic status	20000	Data include: height, weight, waist circumference, blood sugar, blood lipids, blood uric acid, 24-hour urine sodium, urinary potassium, etc.	Trends in obesity in hypertensive patients, change in abnormal glucose and lipid metabolism, and variation in urine sodium/urinary potassium ratios;
Target Organ damage	10000	Data include: electrocardiogram, echocardiography, carotid ultrasound, glomerular filtration rate, serum creatinine, urinary albumin/creatinine ratio, 24-hour urine protein quantitation, pulse wave velocity, sputum/arm blood pressure index, fundus examination, etc.	1. The proportion of various subclinical target organ injuries of hypertensive patients and its correlation with prognosis; 2. Evaluate the subclinical target organ damage examination methods that are relatively simple, less expensive, and easy to promote;
Coexisting clinical disease	30000	Data include: cerebrovascular disease, heart disease, kidney disease, peripheral vascular disease, retinopathy, etc.	The variation of incidence and mortality of hypertensive patients with cardiovascular and cerebrovascular diseases and end-stage renal disease.

1.1 Extraction of Possible Influencing Factors

Judging on Table 1, many factors affect the occurrence of hypertension, and hypertension appear in various clinical symptoms. Therefore, it is necessary to extract and classify the possible influencing factors of the formation of hypertension disease. According to the characteristics of information storage database of information system, the conditional fuzzy query of the relevant fields in the data table are used to extract the rules and count the frequency of occurrence. For example, to count the frequency relationship between "age" and clinical symptoms of hypertension, the basic principles are:

Select count (“age”) From [TableName] Where [ConditionField] like “hypertension” or ClinicalSymptom =“Dizziness” or ClinicalSymptom=“Headache” or ClinicalSymptom = “Palpitate”.....

Factors that occur too few and factors that are clearly not associated with the formation of hypertension and its developmental trends were excluded. Even so, there are still many possible influencing factors left according to this rule. Differentiate the factors by categories, there can be individual factors, habits, environmental factors, drug effects and other diseases. To be specific, the factors include age, gender, weight, height, waist circumference, genetics, occupation, blood sugar, blood lipids, temperature, season, pollution, smoking history and drinking history, exercise volume, family history, past history, medication history, blood uric acid, high sodium diet, mental state, etc.

In addition, kidney diseases, brain diseases, onset time and other diseases are also possible causes that influence the occurrence and development of hypertension.

With this many factors that may cause hypertension, it is difficult to determine the important factors completely by quantitative methods. Even if it is feasible, the probability value of the judgement of importance is too low to distinguish between important and non-important factors. To this end, this paper extracts the factors that are not very clear on the etiology of hypertension diseases, and the factors that are obvious and have important influence on the etiology of hypertension. Such as gender, height, weight, BMI(Body Mass Index), systolic blood pressure, and diastolic blood pressure are directly introduced in the subsequent analysis of the importance of the influence.

1.2 Selection of Important Influencing Factors

As mentioned in the previous section, there may be many influencing factors lacking clear evidence of the cause left by the rule. The Delphi method can be used for further selection.

Delphi is a subjective and qualitative expert decision-making method with three distinct features that distinguish it from other expert decision-making methods. Namely anonymity, multiple feedbacks, and statistical answers. In this paper, seven senior experts and doctors from Shanghai Ruijin Hospital and Medical Union Hospital were invited to form an anonymous expert group and were identified separately. The group selected the influencing factors of hypertension according to Delphi method. The selection process is shown in Fig. 1.

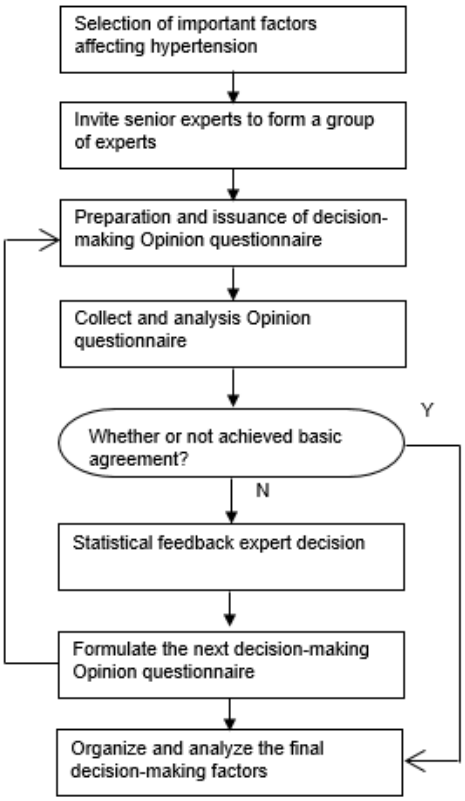

Fig. 1 Delphi method for the selection of important factors affecting hypertension

Experts are required to make judgmental decisions on the importance of each possible influencing factor according to the 1-9 judging method. After three rounds of feedback, the decision opinions given by the experts become consistent. The collected forms and the experts' opinions on each factor are shown in Table 2.

Table 2. The third round, experts judge the importance of each possible influencing factor

expert / factor	1	2	3	4	5	6	7	average value
Liver disease	4	3	4	4	4	3	4	3.71
Age	6	6	7	7	7	7	7	6.71
Mental state	4	3	3	3	3	4	3	3.29
Environmental factor	7	7	7	8	7	8	7	7.29
Habit	7	7	9	9	9	9	8	8.29
Drug factor	8	7	9	7	7	7	9	7.71
Temperature	8	8	7	7	7	8	8	7.57
Season	8	7	7	8	7	8	7	7.43
Gender	2	3	3	2	3	2	3	2.57
Height	2	2	3	4	4	2	3	2.86
Weight	3	3	4	3	4	3	4	3.43
Waistline	4	3	4	3	3	4	3	3.43
Blood sugar	3	3	3	3	4	3	3	3.14
Blood fat	2	2	3	2	2	3	2	2.29
Job occupation	4	8	5	6	9	9	9	7.14
Smoking history	8	7	9	7	7	7	9	7.71
Drinking history	4	8	5	6	9	9	9	7.14
Genetic factor	7	8	9	9	8	8	9	8.29
Past history	3	2	2	3	3	3	3	2.71
Exercise volumn	7	8	8	8	8	9	8	8.00
History of medication	3	2	3	2	2	3	3	2.57
Blood uric acid	3	2	2	2	2	2	2	2.14
Air pollution	9	7	8	8	7	9	7	7.86
High sodium diet	8	7	9	7	7	7	9	7.71
Disease factor	3	3	4	3	4	3	4	3.43
Individual factor	9	8	9	8	7	9	8	8.29
Anti-tumor drugs	7	7	6	7	7	6	7	6.71
Hormonal drugs	6	6	7	7	7	7	6	6.57
Intracranial disease	3	2	2	3	3	3	2	2.57

The influencing factors with an average value greater than 5 are taken as important factors, which are: age, temperature, season, occupation, smoking history, drinking history, exercise volume, environmental factors, habits, drug factors, genetic factors, air pollution, high sodium diet, individual factors, anti-tumor drugs and hormonal drugs. There are still many factors after the selection, and these factors form a cross-cutting or non-cross-cutting subordinate logic relationship. To learn the main influencing factors of hypertension disease formation and its influence mechanism and classification management on hypertension diseases, this paper uses the system structure model to cluster the important factors aftet selection and construct the hierarchical structure of the influencing factors of hypertension diseases.

2. Principle of System Structure Model

The principle of the system structure model can be divided into several major steps: integration influencing factors, constructing adjacency matrix, generating reachable matrix, decomposing reachable matrix and determining hierarchical structure [2]. The main process is as follows.

2.1 Integration Factors

The influencing factors can be expressed as $s = (p_1, p_1, \cdots, p_n)$, where $p_1, p_1, \cdots, p_n$are the influencing factors selected in 2.2, such as genetic factors, age factors, mental factors and environmental factors.

2.2 Constructing an Adjacency Matrix

Having the output (impact) factors as row and the input (affected) factors as column. Compare the selected influencing factors, set value as 1 when the influencing factors have impact on each other, 0 when the factors are independent. That is, the value of each element in the adjacency matrix is determined using the following rule:

$$a_{ij} = \begin{cases} 1 & (p_i \to p_j) \\ 0 & (OR) \end{cases} \tag{1}$$

The adjacency matrix can be expressed as $A = [a_{ij}]$:

$$A = \begin{bmatrix} 0 & 0 & 1 & \cdots & 0 & 1 \\ 1 & 0 & 0 & \cdots & 1 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 1 & 1 & \cdots & 0 & 0 \end{bmatrix} \tag{2}$$

2.3 Generating the Reachable Matrix

Adding the adjacency matrix and unit matrix:

$$A + I = \begin{bmatrix} 0 & 0 & 1 & \cdots & 0 & 1 \\ 1 & 0 & 0 & \cdots & 1 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 1 & 1 & \cdots & 0 & 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & 0 & \cdots & 0 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & \cdots & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1 & \cdots & 0 & 1 \\ 1 & 1 & 0 & \cdots & 1 & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 1 & 1 & \cdots & 0 & 1 \end{bmatrix}$$

Then perform a power operation on the matrix $A + I$ for an integer n until the following formula holds:

$$M \equiv (A + I)^{n+1} = (A + I)^n \neq \cdots \neq (A + I)^2 \neq (A + I) \tag{3}$$

2.4 Decompose Reachable Matrix

Define $p(S_i) = \{S_i | m_{ij} = 1\}$ as a reachable set, $Q(S_i) = \{S_i | m_{ij} = 1\}$ as a antecedent set, L_1 as a set which satisfies $p(S_i) \cap Q(S_i) = p(S_i)$. The influencing factors in L_1 can be reached from other factors, while they can't reach other factors. Which means the factors in L_1 are at the highest level (level 1) and can often be considered as the overall decision goal.

Remove the rows and columns from the original reachable matrix corresponding to factors in L_1, and perform the same operation on the new reachable matrix just obtained to determine the factors in L_2 which belong to level 2. Repeat the same operation to find $L_3, L_4, \cdots$, until all the factors are attributed to the corresponding level.

2.5 Determine the Hierarchy

Once the reachable matrix is decomposed, the factor of the first level is placed on the uppermost layer, the factor of the second level is placed below it, so on and so forth. The hierarchical structure is formed when all the factors are placed from top to bottom in order.

3. Hierarchical Construction of Important Factors Influencing Hypertension

According to the system structure model, the hierarchical construction process of the important influencing factors of hypertension disease is as follows.

3.1 Important Factors Influencing Hypertension

Symbolize the important influencing factors of hypertension disease selected by Delphi method as p_i and show them in a tabular form as Table 3.

Table 3. List of important factors affecting hypertension

Order	Symbol	Order	Symbol
1	factorp_1	10	Genetic factor p_{10}
2	Environment factorp_2	11	Exercise volumnp_{11}
3	Habitp_3	12	Air pollutionp_{12}
4	Drug factorp_4	13	High sodium dietp_{13}
5	Temperature factorp_5	14	Individual factorp_{14}
6	Season factorp_6	15	Anti-tumor drugsp_{15}
7	Job occupationp_7	16	Hormonal drugsp_{16}
8	Smoking historyp_8	17	Hypertensive diseasep_{17}
9	Drinking historyp_9		

Combine the factors into set s, where $s = (p_1, p_2, \cdots, p_n)$.

3.2 Build a Reachable Matrix of Hypertension Affecting Factors

Analyze the relationship between each two factors according to the system structure model. Table 4 shows the adjacency matrix of the important influencing factors of hypertension.

Table 4. Adjacency matrix of hypertensive disease important influencing factors

	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8	p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}	p_{16}	p_{17}
p_1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
p_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
p_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
p_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
p_5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
p_6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
p_7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
p_8	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
p_9	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
p_{10}	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
p_{11}	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
p_{12}	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
p_{13}	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
p_{14}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
p_{15}	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
p_{16}	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
p_{17}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Add the unit matrix corresponding to the adjacent matrix, which forms the initial reachable matrix. Since the reachable matrix and the generation of the hierarchical structure need large calculation, the hierarchical structure is built with the help of information technology.

3.3 Calculation of Matrix M of Important Influencing Factors of Hypertension

Make a power operation of the integer n on the matrix *A+I* until the following formula holds.

The power operation is based on Boolean algebra operations (logical sum and logical product of 0s and 1s), which are 1+1=1, 1+0=0+1=1, 1x1=1 and 1x0=0x1=0.

If $M \equiv (A+I)^{n+1} = (A+I)^n$, then the first level of important influencing factors of hypertension disease has formed. The summary table is formed with reachable set $P(S_i)$ corresponding to matrix M and each influencing factors, antecedent set $Q(S_i)$, and common set $P(S_i) \cap Q(S_i) = P(S_i)$ to determine

the influencing factors step by step, and form a hierarchical structure of the influencing factors. The calculated influencing factor P_{17} is the first level factors affecting hypertension.

After obtaining the first level of the hierarchy, delete the rows and columns of the influencing factors in the original reachable matrix to form a new reachable matrix.

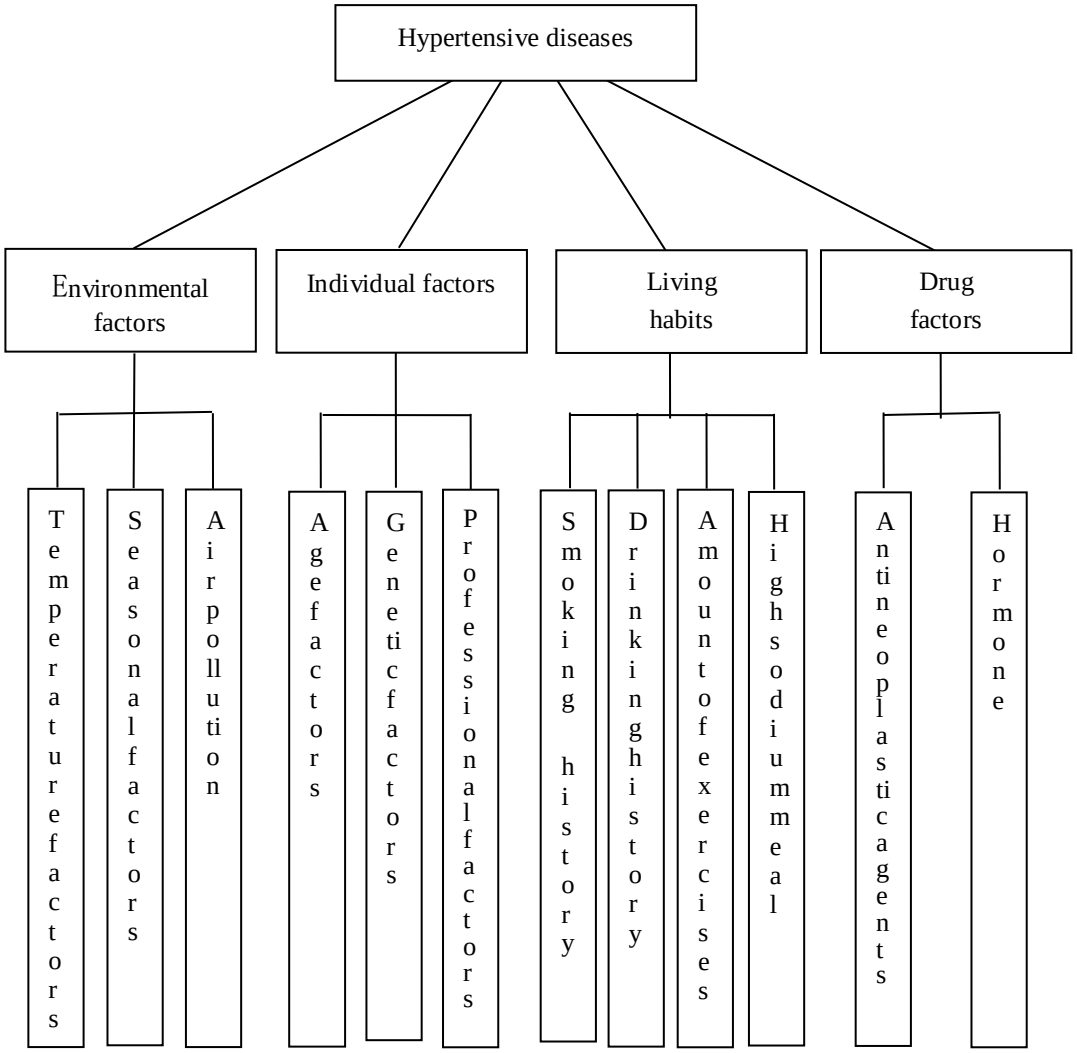

Fig. 2 Hierarchical structure of important influencing factors of hypertension disease

3.4 Generate the Hierarchical Structure of Important Factors Influencing Hypertension

After removing the rows and columns, the hierarchical calculation is continued on the new matrix, and the new summary table is generated to determine the second level of the hierarchical structure.

Since $P(S_i) \bigcap Q(S_i) = P(S_i)$, the level 2 factors that can be obtained for hypertension as P_2, P_3, P_4 and P_{14}, which are environmental factors, habits, drug factors and personal factors. Among them, environmental factors P_2 and temperature factors p_5, seasonal factors p_6 and air pollution p_{12} affect each other; habits p_3 and smoking history p_8, drinking history p_9, exercise volume p_{11} and high-sodium diet p_{13} have an interaction; drug factors p_{14}, anti-tumor drugs p_{15} and hormone drugs p_{16} influence each other; Individual factors p_{14} and age factors p_1, occupational factors p_7, smoking history p_8, drinking history p_9, genetic factors p_{10} and exercise volume p_{11}affect each other.

Smoking history p_8, drinking history p_9 and exercise volumnp_{11} have an interaction with the habits p_3 in level 2 and interact with individual factors p_{14}, which form a cross connection. Remove the rows and columns with determined hierarchy to get the new reachable matrix.

Generate a new reachable set and a new antecedent set to determine the summary table of level 3.

After determining the influencing factors of level 3, the system shows that the hierarchical structure has been generated and each level is labeled.

The hierarchical structure of the influencing factors of hypertension is expressed graphically, and its graphic structure is shown inFig.2.

4. Conclusion

Based on the data of patients with hypertension stored in outpatient and inpatient HIS system in Shanghai Ruijin Hospital and 34 Medical Department Hospital in recent 10 years, this paper get the possible factors affecting the formation of hypertension using the rule extraction and uses Delphi method to select the important influencing factors from the possible influencing factors whose influence on hypertension was not very clear. As well as analyzing the relationship among important influencing factors using system structure model to generate the hierarchical structure of the important influencing factors of hypertension disease. More than that, the paper lays a foundation for further using analytic hierarchy Process (AHP) to calculate the weight of various important influencing factors, and then determine the weight of main influencing factors of hypertension disease.

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