Original Article

Practice of prescription review mode based on data mining in hospital

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Background: Our study aims to solve the problems caused by the large numbers of prescriptions and insufficient pharmacists in the hospital by using a prescription review model based on data mining.

Methods: A hospital pharmacy management analysis and decision system was established based on the data of the hospital information system, requirement of pharmacy management and data mining technology. Based on application of this information system, a four-step data mining prescription review model was created and put into practice, which included presentation of model for prescription evaluation, instance problem model, full-scale extraction of problem prescriptions tracking correction and dynamic monitoring of changes in drug dosage distribution for proposing new problem model.

Results: Through the application of this model, the problems caused by overdosage, over-treatment, the combined use of drugs with the same curative effect, and non-indication use of antibacterial drugs in our hospital's prescription reviews were almost solved. The unreasonable rate of prescriptions has remained below 0.05% since 2015, and the unreasonable rate of doctor's orders has been controlled below 0.24%. The proportion of medicines dropped from 45.4% to 28.2%. The proportion of adjuvant drugs used decreased from 21% to 1.6%.

Conclusions: This data mining prescription evaluation model is an efficient prescription quality management tool suitable for implementation in the digital, big data era.

Keywords: Data mining; prescription reviews; system

Submitted Apr 13, 2020. Accepted for publication Jun 24, 2020.
doi: 10.21037/atm-20-3933
View this article at: http://dx.doi.org/10.21037/atm-20-3933

Introduction

The prescription review is defined as the process of evaluating and standardizing prescription writing and determining the suitability of the clinical use of drugs according to the relevant regulations and technical specifications. The process aims to find existing or potential problems to formulate or implement novel interventions and improvements for promoting the rational use of clinical drugs. Moreover, it is an integral part of the continuous improvement of medical quality and the clinical application of drugs in hospitals. Also, it is an essential means for improving clinical drug treatments in therapeutic levels (1,2). However, due to the shortage of pharmacists, especially clinical pharmacists in Chinese hospitals, prescription reviews are mostly carried out by manual reviewers after a random selection of samples of prescriptions at present (3-5).

This way of prescription reviews results in many problems.

For example, the sample size analyzed is usually too small to reflect all the prescription information. Furthermore, the different ranges of knowledge prevent pharmacists from achieving consistent standards. Also, the evaluations cannot be linked artificially with the previous drug use of patients, so the discovery is only about some superficial drug use problems but not further about irrational drug use behaviors. To meet the requirements of *Standards for Hospitals Prescription reviews* (6), our hospital independently built a data-driven prescription review model based on the data mining technology on a developed system. The system is called, "hospital pharmacy management analysis and decision system". The system and the model changed the former patterns of individual prescription reviews.

Primarily, clinical pharmacists and informatics pharmacists were able to use modern information technology to construct a precise analysis model of irrational drug use, and then, informatics pharmacists used the model to realize full prescription screening process by computer. Once the problem was found, clinical pharmacists turned to clinical confirmation and supervision for correction. Therefore, the model can review full-prescriptions quickly and solve the main problems of clinical unreasonable drug use despite the shortage of clinical pharmacists in China. Now the design and application of the system are introduced as follows.

Methods

Design of the hospital pharmacy management analysis and decision system

System environment

Hospital pharmacy management analysis and decision systems are adopted utilizing an across-platform development language, which can be flexibly deployed on various versions of Windows and Linux operating systems. The system adopted the object relation mapping (ORM) technology and can be compatible with various hospital information system (HIS) data, including the mainstream ORACLE, SQLSERVER database, and some newly developed databases such as MySQL.

The design of system architecture

The system adopted the design of browser-server architecture to ease the deployment, implementation, and the upgrading of the system. It consisted of the front-end user interface, back-end configuration and data analysis, and HIS interface. Through the creation of the drug additional attribute table in the HIS database, the system does a joint search according to the requirements of drug management after matching the drug name, specification, and manufacturer. The detailed architecture is shown in *Figures 1* and *2*.

System functions

HIS search interface

The HIS search interface is implemented by SQL Alchemy software, which not only supplies the SQL toolkit but also provides the ORM tool. It can easily realize system user and configuration management, and can flexibly search various HIS databases, and is compatible with the search functions of many databases such as SQLite, MySQL, Postgres, Oracle, MS-SQL, SQL Server, and Firebird. The interface mainly provides the functions of adding, deleting, changing and checking the "Drug Additional Attribute Table" created in the HIS system database, as well as the joint search on the data tables related to the pharmaceutical management in the HIS database.

The role function management module (7)

This module adopts the role-based user permission configuration design pattern. The relationship between the roles, users, and permissions are that (I) permissions are only associated with roles. (II) A user can have several roles, and a role can be assigned to several users. The system administrator can define several roles and grant each role the corresponding permissions, and then assign them the corresponding roles to each user. This series of processes completes the user authorization. When a personnel change occurs, the corresponding authority can be assigned to the new user if the corresponding role is assigned to the new user. The design pattern has a great authority management function that is accurate and flexible, the system can be self-prepared for each unit management mode, and the universality of the software is greatly improved.

Standard drug library comparison module

The module uses natural language processing (NLP) technology and regular expression matching technology to compare the drug name, specification, manufacturer, and other information between the drug dictionary table and the drug attribute classification knowledge base in HIS. Next, it realizes data and shows the correspondence of the two-drug codes of "HIS database" and "drug attribute classification knowledge base," which is prepared for expanding the drug attributes in the HIS database.

On this basis, the drug attribute classification information table can be set up in the HIS database and the related

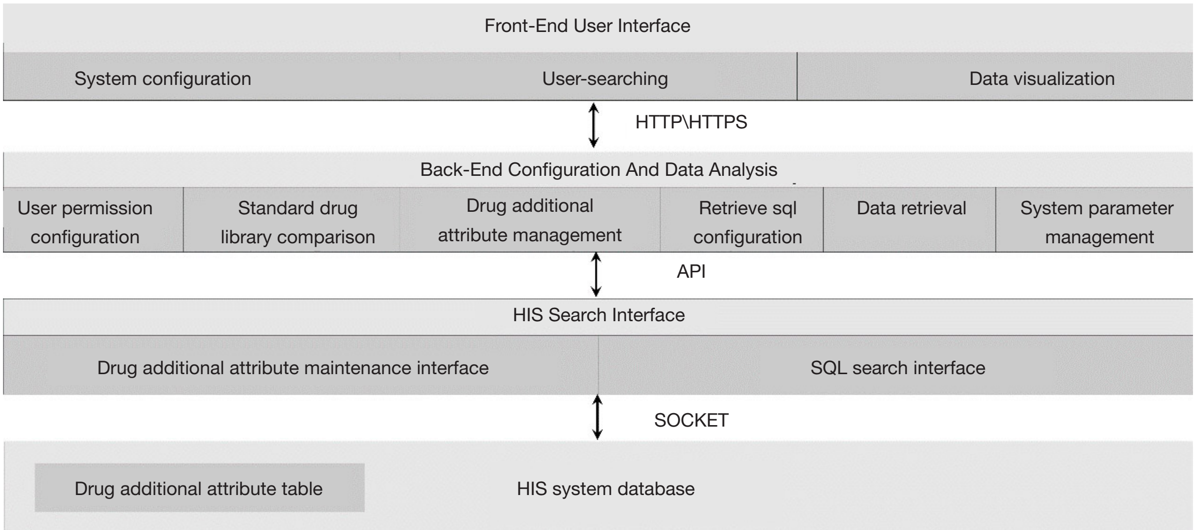

Figure 1 Framework of hospital pharmacy management analysis and decision system.

Figure 2 Interface of the hospital pharmacy management analysis and decision system.

information of each drug attribute on pairing. For example, this can include commodity information classification, treatment attribute information classification, material attribute classification, and so on. Then, the data is written into the table, which is used to analyze the correlation of prescription from pharmacological classification, medical insurance drug classification, pharmacoeconomics classification, drug commodity classification, and so on. Through this module, the ability of drug-related data analysis is expanded. Users can use any classification item in the attached attribute table of drugs for aggregation search, to realize the multi-perspective analysis of hospital drug use data with drug attributes as the source of analysis.

Search item configuration module

This module is used to write and debug the SQL statements related to the pharmaceutical management related to the searches in the HIS database. Through the application of this module, the system maintainer can add the new search statistics functions by writing a simple SQL search statement and does not need to write any code for the system. What is more, the parameter configuration functions of this module can realize the automatic generation of search pages with parameter search items.

Additionally, when users search for data, they only need to fill in the parameters to realize it. After the search instruction is issued, the module will preprocess the SQL statement, convert the character set, assign the system variables used in the search, search different types of HIS databases through the database search engine, and format the returned data. The results that correspond to the same search conditions are saved to improve the speed of data access. The settings of this module reduce the new functions threshold of the system and new search pages development. Users can easily add new search models and pages if they know the SQL language.

Data visualization module

Data visualization is used to display the results of user searches, including data association display, multi-type data chart displays, and data export. The system applies the ECHARTS data chart for data display. It is a front-end map library, is compatible with most browsers, supplies a visual, vivid, interactive, and highly personalized data visualization chart. All data search items can be exported to the specified format file, such as excel, txt, pdf, etc.

System advantages

The system reduces the difficulty of developing new search items and new pages. The user can easily add a new search model and a page as long as the SQL language is known, and the model can be shared for use. The system runs in a hospital local area network, and all the search operations are dependent on the HIS system. Therefore, all operations of the system are transparent to the HIS administrator. Therefore, the HIS administrator can timely monitor whether the system user has performed illegal search operations on the HIS and ensure the security of HIS data management. The front-end user interface of the system runs on the browser, and the user does not need any deployment. At present, four categories and 45 items of pharmaceutical management analysis models that can be popularized and applied are shown in *Figure 3*.

Prescription review model of data mining

Based on the application of hospital pharmacy management analysis and decision system, the hospital prescription evaluation model has been reconstructed. The previous methods of randomly selecting samples of prescriptions/doctor's orders have been changed, and the establishment of a data-driven prescription review model has been explored. Under this model, prescription reviews were divided into the following four steps to iterate repeatedly, which included clinical pharmacist's presentation of a model for prescription evaluation, informatics pharmacist's instance problem model, full-scale extraction of problem prescriptions and problem correction, dynamic monitoring of changes in drug dosage distribution for proposing new problem model.

Proposal for a prescription review problem model

The clinical pharmacist's group qualitatively analyzes the specific unreasonable drug use problems one by one. It extracts the characteristics of these problems through the summary of the unreasonable drug use tendency in the current hospitals and the collective discussion of the rational drug use group in the hospitals. The demand for search and analysis of the core data of pharmaceutical management is also put forward here, such as the proportion of drugs, the ranking of drugs for the drug sales amount, the utilization rate of antibiotics, the intensity of antibiotics uses, the utilization rate of antibiotics in class I incisions, and so on.

Model instantiation

The informatics pharmacist applies the hospital pharmacy management analysis and decision system. This is done to compile SQL statements and form new review search items according to the control points proposed by the clinical pharmacists through the function of inquiry item configuration. The informatics pharmacists use these newly compiled search items to sample the doctors' orders, and the clinical pharmacists confirm the accuracy of the extraction. Through the repeated iterations of these steps, correct and credible search items (models) can be obtained. This search item can be used by all permission users after authentication.

Full-scale extraction of problem prescriptions and problem correction

The clinical pharmacist applies the hospital pharmacy management analysis and decision system to fully extract

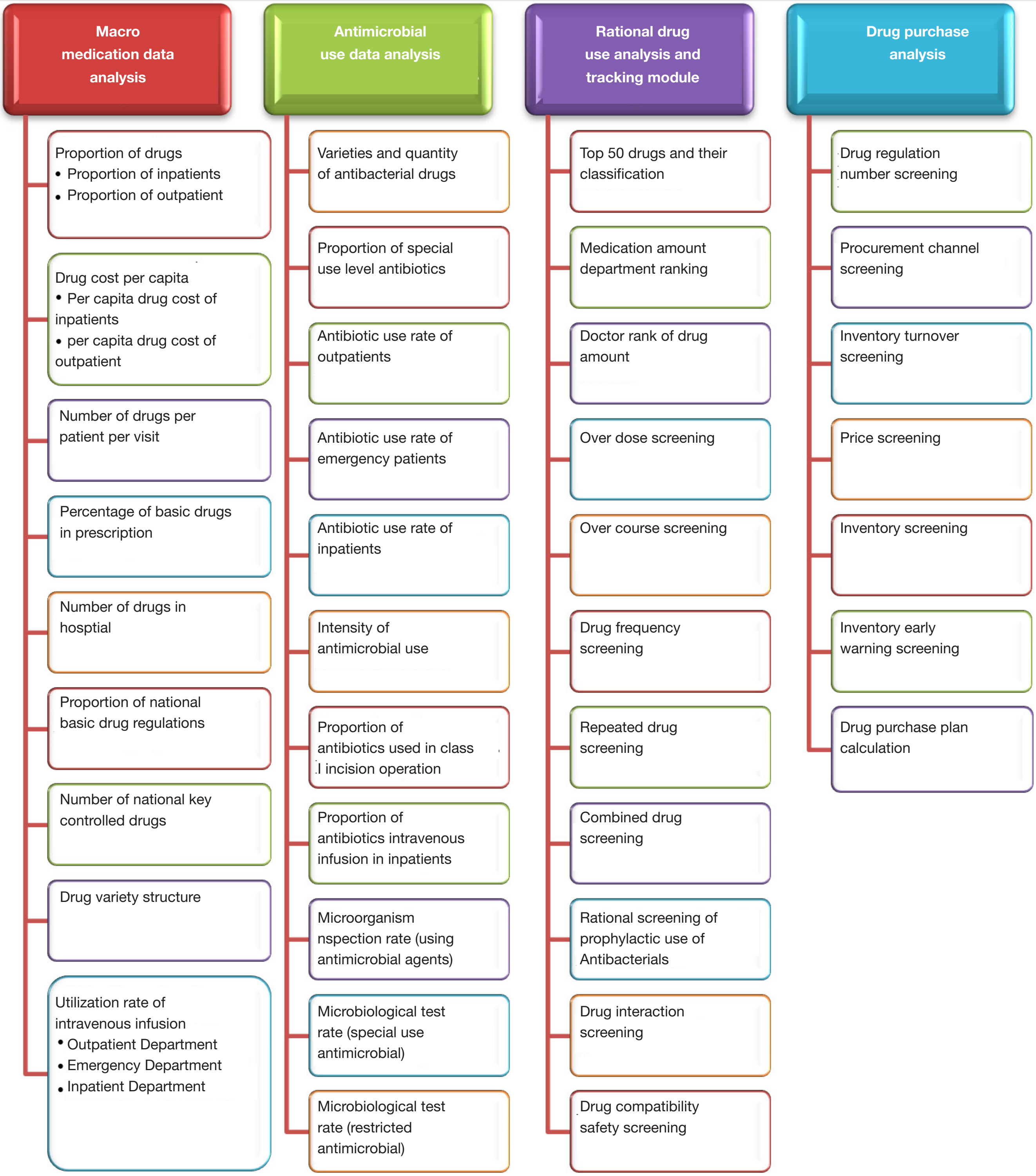

Figure 3 Analysis models of hospital pharmacy management analysis and decision system.

the target problem prescription. Then, after the division of the problem, the clinical pharmacist in charge of each of the departments will communicate with the medical staff from each department one-by-one according to the problem with the prescription/doctors' orders, and put forward suggestions for improvement.

The accuracy of the model was determined by the experiment, and the extraction accuracy of the early-stage problem model was considered by the rational drug use group. Therefore, in this step, communication between the clinical pharmacist and the medical staff is more about problem identification and education. Particular problems for individual doctors will be communicated with separately, and clinical pharmacists will uniformly explain the common problems to the departments at the department transfer meetings. At the regular expert review meeting on rational drug use, the pharmacy department will discuss the classification of the problem, and the clinical pharmacist will report on the communication and the confirmation of the problem. Severe penalties for obvious and recurring medication problems are linked to incentive performance benefits and promotions; warnings are given about first-time bias.

Dynamic update of the review model

Regular clinical pharmacists apply the hospital pharmacy management analysis and decision system for the drug structure analysis module to retrieve the drug consumption structure of the divisions in charge. These applications focus on drugs with substantial amounts and high consumption and high weekly growth. At the same time, the reasonable application analysis module of antibiotics was used to detect the utilization rate of antibiotics, the intensity of use, and the utilization rate of class I incision antibiotics in the department of management. In this link, clinical pharmacists focused on new anomalies and unreasonable drug use. During the investigation stage, the clinical pharmacist will communicate with the relevant medical personnel one by one, understand the actual situation, and make suggestions. If the problem model has the screening value, the clinical pharmacist will give the unreasonable drug use to the reasonable medication group for review. Through the continuous summarization and accumulation of this link, the current prescription review screening model of our hospital has been more than 30, and the advancement of the data-driven review mode has been realized.

The construction of the prescription review model based on data mining and its application case

Over-medication and misuse of drugs not only lead to a waste of medical resources but also cause widespread health hazards. The repeated medication is referred to as prescribing two or more drugs with the equally pharmacological effects at the same time for the same patient without any justification. It will not only increase the drug dosage but also enhance the adverse reaction and side effects. What is more serious is that it is economically damaging and life-threatening to the patient. There are three main reasons for this problem. Firstly, the lack of responsibility for prescribing doctors; some doctors did not detailed study the history of the patient's medication before prescribing so that the prescribed repeatedly. Secondly, some patients have repeatedly been prescribed the same drugs in the multi-disciplinary clinic to take medical insurance funds. Thirdly, some doctors prescribed a large prescription for patients by breaking down prescription behavior. Management and control of repeated medication based only on manual review of prescriptions has little ability to find the decomposed prescriptions due to the inability to associate the previous medication information of patients. It also has the problem of inconsistent standards and omission caused by the differences in knowledge levels of individual doctors. The establishment of a data-driven prescription review model and its application case will iterative process according to the following procedure.

The definition of repeated medication behavior

Clinical pharmacists have redefined the definition of repeated medication according to *The Guide for Special Review of Prescription for Beijing Hospitals* of the year 2019. The pharmacists divided it into the following three levels: (I) the same drug is prescribed for the same patient more than 2 times at the same time; (II) a drug that contains the same effective component but has a different generic name is prescribed to the same patient at the same time; (III) similar drugs with the same mechanism of action are prescribed for the same patient at the same time.

The construction of the model for first-level repeated medication screening and its application

The informatics pharmacist interpreted the definition of the first-level repeated medication, which is the same drug is issued for the same patient more than two times at the same time. The doctor prescribed the same drug for more than or equal to two times in the same day for the same patient to create the feature judgment model. When transforming this feature judgment mode into computer logic language, it becomes (I) patient ID is the same: ensuring the prescriptions are prescribed for the same patient; (II) the prescription time is within one day: prescribing multiple prescriptions for the same drug on the same day will be considered a suspected repetitive drug; (III) one drug name appears more than two times in the same patient prescription. The SQL statement for the screening model is as follows:

1. Select patient_id, visit_date, drug_name, count(*) as repeat_times
2. from prescription_table
3. where visit_date >= (the date of investigation started) and visit_date < (the date the investigation ended)
4. group by patient_id, visit_date, drug_name
5. having repeat_times>=2
6. order by repeat_times desc

The prescription_table is a simulated outpatient prescription record table in which the patient_id (patient ID), visit_date (prescription date), drug_name (drug name), drug_spec (drug specification), amount (quantity), etc. are recorded. The patient_id, visit_date, drug_name, and repeat_times in the query results will indicate the patient ID, prescribing the time, name of the repeated medication, and the number of repetitions, respectively.

After obtaining the above information, the clinical pharmacist can confirm the specific repeated medications through the prescription inquiry system and communicate with the prescribing doctor to prevent a first-level repeated medication issue from happening. The behavior of repeated medication found after the initiation of the first-level repeated medication model is the actual repeated medication behavior of the patients. This actual repeated medication behavior is reflected in the fact that the patients required several doctors to prescribe the same drugs for them in different rooms. These kinds of patients are suspected of taking out medical insurance funds and reselling them.

The construction of the model for second-level repeated medication screening and its application

The informatics pharmacist interpreted the definition of second-level repeated medication, which is a drug that contains the same effective component but has a different generic name is prescribed to the same patient at the same time, to a feature judgment model: the doctor prescribed the same patient with drugs containing the same principal component for more than or equal to 2 times in one single day. In the computer logic language, it is: (I) patient ID is the same: ensuring the prescriptions are prescribed for the same patient; (II) the prescription time is within one day, i.e., prescribing multiple prescriptions for the same drug on the same day will be considered a suspected repetitive drug; (III) drugs containing the same principal component appear more than or equal to two times in the prescription of the same patient. The establishment of this screening model requires the classification and marking of principle components for all drugs in use. The SQL statement for the screening model is as follows:

(I) Creating a drug principal component dictionary table: main_drug. The fields include drug_id (drug ID), drug_name (drug name), and drug_main_component (principal component). The clinical pharmacy staff should complete the maintenance of the main components of the drug during the investigation period.

(II) Creating an association query model:

1. Select patient_id, visit_date, drug_main_component, count(*) as repeat_times
2. from prescription_table , main_drug
3. where visit_date >= (the date of investigation started) and visit_date < (the date of investigation ended)
4. and prescription_table. drug_name = main_drug. main_drug
5. group by patient_id, visit_date, main_component
6. having repeat_times >= 2
7. order by repeat_times desc

The clinical pharmacist can confirm the specific second-level repeated medication through the prescription inquiry system after obtaining the above information, and communicate with the prescribing doctor to prevent the occurrence of this behavior. The repetitive medication behavior found after the second-level repetitive drug screening model was initiated after the patient's diagnosis and treatment of different diseases in different departments. The third-level of repeated drug screening model method is similar to the second level; the only difference is that the query model needs to establish a drug classification information table (lable each drug with its pharmacological classification). The model should be based on the drug information during the investigation period, and then established as a correlation query with the drug prescription information table to obtain the data sets of repeated medication for drugs with the same mechanism of action.

Construction of universal repeated medication screening model

In the above-repeated medication screening model of all three levels, the time frames for defining repeated medication are all designed as one day. Nevertheless, this is just a special case of repeated medication. In the real world, when we take a patient-centered view of their medications, we can find that as long as the patient revisits the hospital during the continuous use of the drug, there is a risk of repeated drug use. At the same time, if the patient or doctor does have misconduct such as taking medical insurance or taking a drug, it does not necessarily occur repeatedly on the same day. Therefore, data mining methods are needed to mine the underlying features from a large number of prescriptions. Discovering repeated medication is only the first step in screening, correlating past behaviors through big data analysis to finally classify problems. Only by truly distinguishing communication problems, technical problems, specific doctor problems, and specific patient problems, pharmacists can achieve precise control of repeated medication. Therefore, the method for repeated drug screening should be further iterated into the following model.

The number the prescriptions, extract the prescription information, and create a prescription information form.

Screen out the information of patients who have been prescribed more than two same drugs or two drugs with the same pharmacological action and the same main ingredient.

Make a loop judgment for each patient selected to determine whether the patient has repeated medication behavior or not by confirming if there is a time overlap in the use of more than one same drugs or drugs with the same pharmacological action and the same main ingredient. Establish a repeated medication data sheet for storing information about patients who have repeated medication behavior.

The Fuzzy C-Means (FCM) algorithm was used to classify the situation of patients with repeated medication automatically and to identify the severity of repeated medication based on the key indicators of repeated medication (basic patient information, repeated medication days, number of times of repeated medications, drug types, drug DDDs number, amount, prescription doctor's department and title).

The FCM algorithm clusters the data of the patient-related parameters and the doctor-related parameters. In the case of pre-defining, the number of clusters, the membership function, and the iterative algorithm is used to cluster the data according to the features automatically. Specific steps are as follows:

The data is cleaned to form a sample set X={x_1,x_2,...,x_n}, where n is the sample size, and k is the number of classes. The objective function is defined as:

$$J_f(W,Z)=\sum_{j=1}^{k}\sum_{i=1}^{n}\left[\mu_j(x_i)\right]^b\left\|x_i-m_j\right\|^2 \quad [1]$$

where b (b>1) is the fuzzy index, whose default is 2, m_j(j=1,2,...,k) is the center of each cluster, $\mu_j(x_i)$ is the degree of membership to which sample i belongs to class j.

When making the partial derivation of J_f to m_j and $\mu_j(x_i)$ zero, the necessary condition for obtaining the minimum value of the Eq. [1] is:

$$m_j=\frac{\sum_{i=1}^{n}\left[\mu_j(x_i)\right]^b x_i}{\sum_{i=1}^{n}\left[\mu_j(x_i)\right]^b} \quad [2]$$

$$\mu_j(x_i)=\frac{\left\|x_i-m_j\right\|^{-2/(b-1)}}{\sum_{s=1}^{k}\left\|x_j-m_s\right\|^{-2/(b-1)}} \quad [3]$$

The iterative algorithm is used to solve the Eqs. [2] and [3] until the convergence condition is satisfied, and the best solution is obtained.

Taking the maximum value $\mu_t(x_i)$ of the membership degree in $\mu_j(x_i)$, then the sample belongs to the t-the cluster center, thereby completing the classification of the degree of repeated drug use for patients.

For patients at distinct levels of repeated medication or doctors at different levels of repeated prescription, their feature details are shown in the classification and then clustered.

Figure 4 showed the structure of the universal repeated medication screening model. This universal model can not only collect the information about repetitive medication prescriptions in full but also perform a feature classification in prescribers and patients according to their repeated medication grading. This function aids clinical pharmacists to perform the property discrimination of repeated medication behaviors.

Results

Through the practice and application of this prescription review model, the problems of overdose, over-treatment,

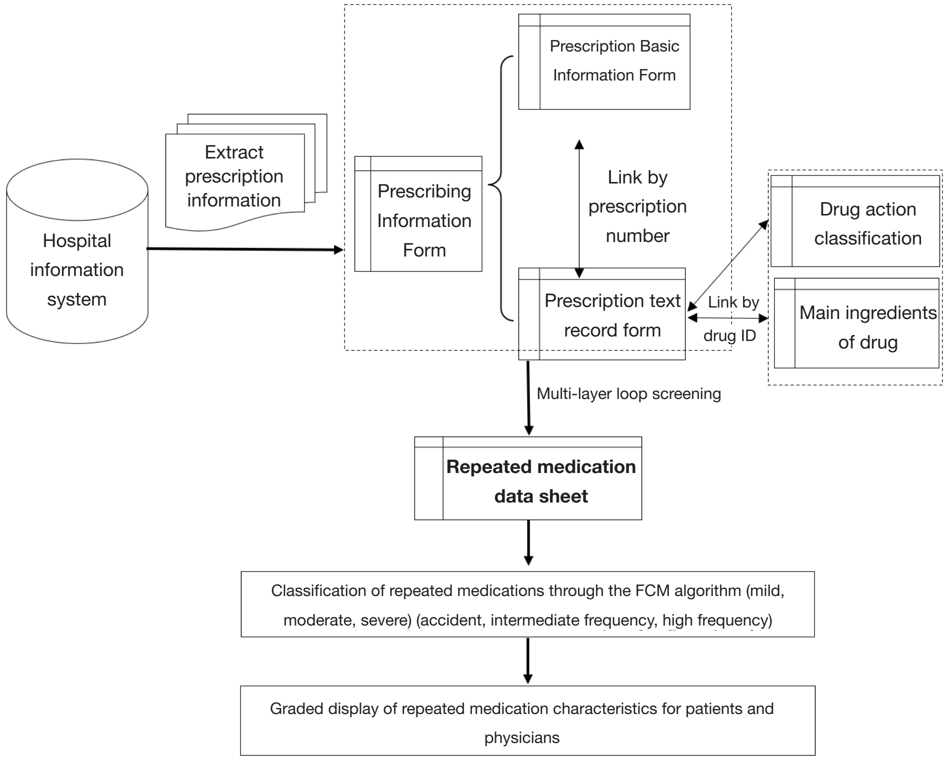

Figure 4 Structure chart of the universal repeated medication screening model.

the combined use of drugs with the same curative effect, and non-indication use of antibacterial drugs in our hospital's prescription reviews no longer exist. The unreasonable rate of prescriptions has remained below 0.05% since 2015, and the unreasonable rate of doctor's orders has been controlled below 0.24%. From the macro data point of view, the antibacterial control index has continuously met the national and military requirements since 2015 under the premise of a fast cure and improvement rate (more than 95%). The current antibacterial use rate is 5.18%. The emergency antibacterial use rate is 24.13%. The antibacterial use intensity is 32.16. The inpatient antibacterial use rate is 39.1%. The use rate of type I incision prevention is 11.2%. The rate of submission of microbial samples (restricted antibacterial drugs) is 61.02%.

The rate of submission of microbial samples (particular antibacterial drugs) is 91.71%. The proportion of medicines dropped from 45.4% to 28.2%. The proportion of adjuvant drugs used decreased from 21% to 1.6%.

Discussion

When a prescription review mode based on data mining was used, all prescriptions were screened by a homogenization analysis model. As a result, it was only required to have a small number of clinical pharmacists for prescription review monitoring. For young pharmacists using this mode, the learning and application of the drug analysis model are essential to learning the fundamentals of the prescription review process from experienced senior clinical pharmacists directly.

Learning the process also allows for the rapid growth of professional skills through their confirmation of drug problems in suspicious cases. For all pharmacists, improving one's professional skills, finding new and potential irrational drug use behaviors, updating and creating an analysis model of irrational drug use will become essential to their work. Diversifying their work is vital to avoiding simple case browsing, writing drug use cases, or simple drug dispensing work. At the same time, pharmacists will have more time to do well in clinical pharmaceutical care.

Under the control of this model, the phenomenon of missing problem prescriptions will not occur, which frequently happens under the current model of manual random inspection. The problem of repeated medication was corrected more thoroughly, and the final clinical medication structure will change significantly, which means changes in the hospital medication ecosystem were achieved through the control of prescription review model based on data mining.

With the rapid changes to the hospital medication ecosystem, the screening models that are in current use have lost their effectiveness. Pharmacy information technicians are required to work with senior clinical pharmacists to abstract and establish several new screening models for drug use and to adapt to the new ecologies of drug use and improve the level of hospital medication so that they can deal with new changes and needs. For example, in the past, the clinical application of traditional Chinese medicine injections for promoting blood circulation and removing blood stasis, the problems with over-dose and over-course often occurred. When the problematic prescription was detected by full screening and improved from clinical pharmacists to clinical supervision, the problem of over-dose and over-course of traditional Chinese medicine injections of promoting blood circulation and removing blood stasis of the same species no longer exists. However, subsequent cases of the same type of traditional Chinese medicine injections for promoting blood circulation and removing blood stasis were changed back and forth increasingly. When clinical pharmacists discover this new predisposition problem, they should construct a new analysis model for the problem of switching drugs with the same function with informatics pharmacists to correct the above situation.

During the construction of prescription review mode based on data mining, several problems and difficulties were encountered. For example, there were inadequate data access rights; analysis of the models was too complex and difficult to implement; many false-positive results were found in the screening, among many others. The biggest problem we encountered is that the data records of the hospital information system were not filled in properly, and the data items are incomplete. This problem will lead to a series of typical irrational drug use problems that can not be obtained through the analysis model. For example, up to now, analysis models of drug use without indications are challenging to achieve any success. The main reason is that the information of the patient's condition diagnosis is not written according to the ICD10 standard, but the doctor fills in the information by himself using natural language, which makes it challenging to identify. However, we firmly believe that with the continuous standardization of the hospital information system, these problems will be solved in the future.

Conclusions

Prescription review mode based on data mining is an efficient and fast prescription quality management model adapted to the current era of big data, and our hospital has only tried the feasibility of this model through nearly five years of practice. The practice and application of big data-based analysis technology and data mining related algorithms will supply more professional and correct data support for this model. Screening models for irrational drug use accumulated in the practice of this model can also be used as an audit model for pre-prescription review systems, which can prevent a series of unreasonable drug use beforehand.

Acknowledgments

Funding: Training program for young and middle-aged academic and technical leaders in Yunnan Province (No. 2017HB052).

Footnote

Data Sharing Statement: Available at http://dx.doi.org/10.21037/atm-20-3933

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/atm-20-3933). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Xu F, Yin J, Zeng S. Practice of prescription review mode based on data mining in hospital. Ann Transl Med 2020;8(14):885. doi: 10.21037/atm-20-3933