The Construction of a Clinical Decision Support System Based on Knowledge Base

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Abstract. Based on a review of domestic and foreign research, application status, classification, composition, and the main problem of a clinical decision support system, this paper proposed a CDSS mode based on a knowledge base. On KB-CDSS mode, this paper discussed the architecture, principle, process, construction of the knowledge base, system design, and application value, then introduced the application WanFang Data Clinical Diagnosis and Treatment Knowledge Base.

Keywords: Clinical Decision Support System, CDSS, Knowledge Base

1 Background

Errors made by medical staff in the health care activities have become a social problem of common concern at home and abroad. In 1999, the research report "To err is Human," published by the Institute of Medicine (IOM), noted that the number of medical errors was alarming. Death caused by medical errors has been ranked No. 5 among the top ten causes of human death. Medical errors caused by human factors account for a large proportion of errors, but most of such medical errors can be avoided by the operation of a computer system. Therefore, how to improve medical quality, control medical errors, and enhance patient safety have become urgent tasks for the current health care sector. Accordingly, clinical decision-making research has gradually become an important field in clinical medicine [1].

Doctors need to have a relevant knowledge of disciplinary expertise, drug, examination, diagnosis and treatment, etc., to make scientific clinical decisions. General practitioners and interdisciplinary doctors are required to have more knowledge.

A high quality design of Clinical Decision Support System (CDSS) can provides guarantees to compensate the limitations of doctors' clinical knowledge, reducing human negligence regarding diagnosis, treatment, examination, and drug use and avoiding repeated treatment and unnecessary medication; however, there are few

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CDSSs that can be widely applied to clinical treatment at home and abroad. The main reasons include great difficulty in the combination of computer science and clinical work mode, difficulties in the construction of an authoritative knowledge base, rapid updating of medical knowledge, more clinical diagnosis uncertainties, and complex inference mechanisms. Based on this, our team integrated a variety of limitations in the study and practice, proposed the idea of building a CDSS from the perspective of the medical knowledge base, and made attempts to do so [2], [3], [4], [5], [6], [7], [8].

2 The status of CDSS

2.1 Definition and development status of CDSS

Currently, there are many definitions of clinical diagnosis and treatment knowledge systems. Combining them, a CDSS is an expert system that provides decision support and serves as a diagnosis and treatment reference for clinicians or patients, with any patient-related clinical data as input information and in combination with clinicians' work as well as a knowledge base and reasoning analysis.

The world's first fully functional CDSS was MYCIN, developed by Stanford University in the 1970s. MYCIN is mainly used for diagnosis and treatment of bacterial infections. CDSSs with different functional characteristics emerged later, such as QMR of the University of Pittsburgh, HELP of the University of Utah in Salt Lake City[12], Uptodate of Wolters Kluwer[13], [14], [16], Elsevier's MD Consult[15], [17]and so on.

China's CDSS was developed late and is mostly still in the theoretical research stage. There is a large gap compared with foreign countries. The existing CDSS mainly gives priority to single-disease or single-discipline diagnosis and mostly remains in the stage of theoretical studies and laboratory studies, such as the OCDSS of Shanghai University[18], the bone tumor aided diagnosis system of the Fourth Military Medical University[19], the urology clinical decision support system of Chongqing University[20], the intelligent decision support system of acute myocardial infarction diagnosis of Harbin Institute of Technology[21], and the neurosurgery clinical decision support system of Fudan University[22].

2.2 Classification and main components of CDSS

In Lei Jianbo's "Core Value and Clinical Decision Support of Electronic Medical Records",CDSSs can be classified according to their internal decision-making mechanisms, system functions, method of recommended, man-machine interaction, communication, and extent of decision support.(table. 1) [12]

The application of CDSS and electronic medical record (Electronic Medical Record,EMR) is closely related.In the EMR Adoption Model (EMRAM) developed by HIMISS Analytics and the Application Level Grading Evaluation Methods and Standards of Electronic Medical Record System Function (Trial) launched by China's Ministry of Health, the requirements of CDSS in different levels of EMRs are also

different. [24], [25].
CDSSs are generally composed of a database(scientific data such as clinical pathways and clinical guidelines, and empirical data such as evidence-based literature and case reports), human-computer interaction and logical reasoning, a user interface, and users(doctors, nurses, and inspectors) (Fig. 1).

Table 1. Classification of CDSS Dimension

Classification of dimension	Content
Internal decision-making mechanism	Based on Bayesian algorithm, decision tree analysis, predetermined rule process approach, neural networks, similarity algorithm
System function	Determination of the current diagnosis, follow-up strategy for current diagnosis
The recommended way	Automated alerting (active), active queries (passive)
Man-machine interaction	Standalone system (can independently exist), integration system (integrate with other systems)
Communication way	Consultant way, criticism way
The degree of decision support	Directly (give decision conclusion), indirectly (provide decision-making reference)

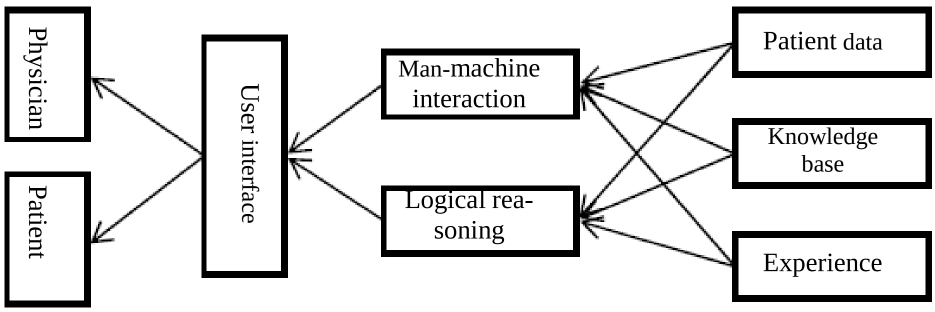

Fig. 1. Main components of CDSSs

2.3 Problems of CDSSs

Although there are many theoretical and system development studies on CDSSs at home and abroad, CDSSs have not yet been widely used on a large scale, the main reasons for which are as follows:

1. CDSSs involve difficult interdisciplinary problems of computers, clinical medicine, psychology, etc. Any CDSS developer who does not have profound clinical knowledge will not be able to meet doctors' demand.
2. CDSSs require a strong and authoritative clinically relevant knowledge base. It is not difficult to build a single-disease or single-discipline knowledge base, but it is very hard to build a knowledge base that can meet all disciplines.
3. Clinical medicine is a rapidly growing discipline. Rapidly updating medical

knowledge and conflict among medical views are also factors limiting the usefulness of CDSSs.

4. CDSSs can only achieve their maximum value by closely combining with HIS/EMR systems. Currently, except in large general hospitals, most medium and small hospitals have not established a perfect HIS/EMR system, which also limits CDSSs' ability in the actual docking.

Although CDSSs face many problems, more and more clinicians need the support of a CDSS for making clinical decisions on information acquired in the hospital. Currently, theoretical research on CDSSs, computer technology, and Internet technology has developed greatly, which also provides a good environment for the application of CDSSs. A growing number of HIS manufacturers and medical publishers are entering this market.

3 Construction of a CDSS based on a Clinical Knowledge Base

3.1 KB-CDSS Construction Ideas and Structure

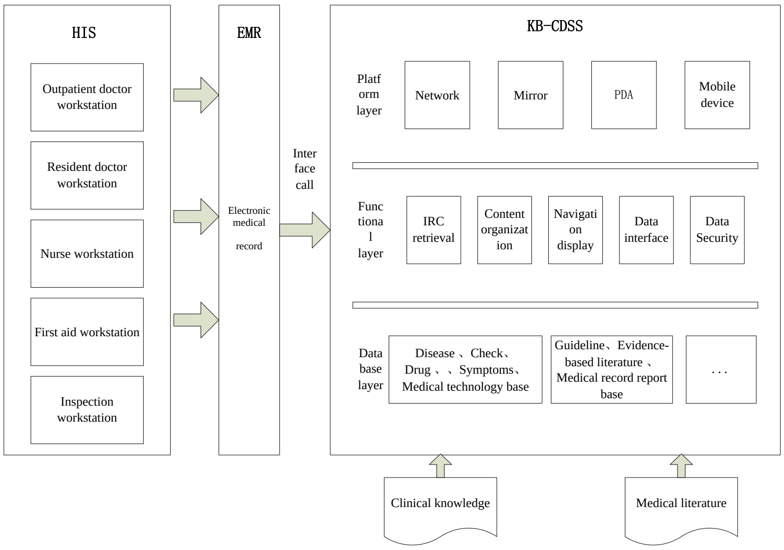

Fig. 2. KB-CDSS Architecture

Based on the current development status of and demand for a CDSS and combined with our rich experience in the construction of large-scale databases, our team proposed Knowledge Base-Clinical Decision Support System (KB-CDSS), which creates different types of clinical databases on the basis of clinical knowledge and vast literature; provides a variety of services for different platforms including organization, search, navigation, interface, and security technology; and offers targeted, timely content according to the user's needs through the interface technology embedded in the electronic medical record system, with the architecture shown in Fig. 2.

3.2 Construction principles

The KB-CDSS-based system architecture mainly sticks to the following principles in the construction process:

1. Authoritative content: The knowledge bases supporting KB-CDSS are all written and audited by physicians with extensive clinical experience. Writers and auditors are all served by physicians with vice-senior titles or above and certain academic achievements in their disciplines.
2. Content objectivity: The knowledge sources of the knowledge bases supporting KB-CDSS all refer to openly published information required not to contain personal subjective points of view and that underwent a process of text editing review and expert content review.
3. Modularity: Based on the different types of resources, KB-CDSS is divided into a clinical knowledge base and a clinical document base. The basic clinical knowledge base includes a disease base, a symptoms base, a check base, and a drug base. The clinical document base includes clinical-related academic literature, such as guide specifications, case reports, system evaluations, and meta-analyses. Knowledge bases are maintained and regularly updated by experts in various fields to make it easy for clinicians to gain the latest knowledge. In terms of service, they are divided into literature services, knowledge content services, client services, and interface services.
4. Low coupling: KB-CDSS docks with the EMR system through the system interface. The benefits of using this method are that on the one hand it reduces the cost of the EMR developer so that KB-CDSS data can be called through the interface, while on the other hand it reduces KB-CDSS operation problems, which will not affect the normal operation of the EMR.
5. Immediacy: The clinician in the diagnosis process usually requires immediate decision feedback to facilitate the development of treatment programs. KB-CDSS is able to automatically provide relevant content for instant reference through the internal mapping and retrieval mechanism according to the information in CPOE(computerized physician order entry).
6. Relevance: Clinical treatment involves a variety of disciplines and tasks as well as different use groups. KB-CDSS can be customized for different clients according to different user roles and tasks to provide users with closely related content.
7. Low interference: Doctors' diagnostic process is a highly centralized procedure. The doctor needs support only when encountering insurmountable problems or when failing to make a determination, so the KB-CDSS only provides support in the form of reminders when doctors need them.

3.3 The clinical workflow

Clinical diagnostic work involves many roles, such as doctors, patients, nurses, and inspectors. Each role at different stages requires different degrees of clinical knowledge support.

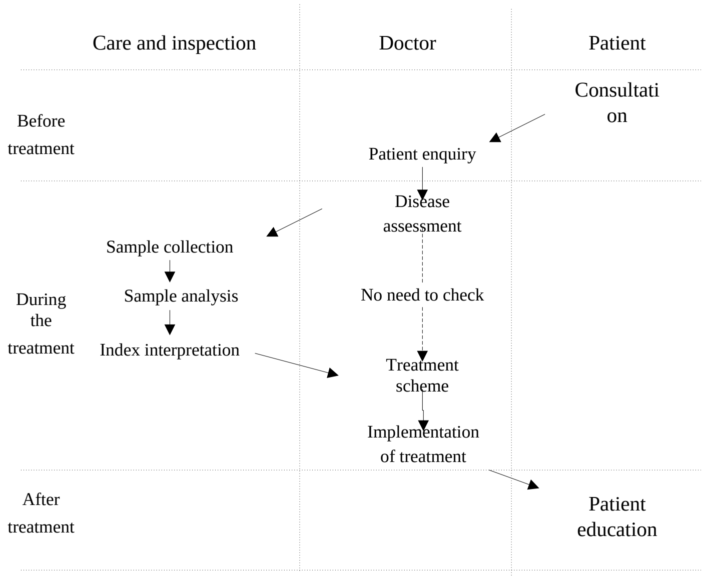

Fig. 3. Clinical workflow

Before treatment, patients need to have an understanding of their own symptoms and disease to provide a reference for effective treatment. Doctors conduct inferential analysis according to the patient's description. The main input information at this stage includes patient history data and descriptions of symptoms. Based on this information, the doctor determines the initial disease. KB-CDSS provides relevant descriptive reference information for support.

In the treatment process, the doctors make a determination according to the patient information. If necessary, they arrange for the patient to be tested to provide more patient information to develop and implement disease treatment programs. At this stage, KB-CDSS is divided into active and passive methods of support. The active method is aimed to prevent the serious consequences of improper treatment emerging in the treatment program, such as disease drug contraindications and drug incompatibility. The passive method means that physicians acquire relevant evidence regarding their decisions according to their experience, including basic knowledge and guidelines on diseases, medicines, examinations, system evaluations/meta-analyses, and case reports.

After treatment, Most of the time patient treatment time is short, and there is a lack of relevant health information literacy. KB-CDSS can provide some support for patient education, as shown in Fig. 3.

3.4 Construction of the Clinical Knowledge Base

The clinical knowledge base is the basis of KB-CDSS. The richness and authority of the knowledge base has a direct impact on the application effect of the system. According to the characteristics, the knowledge base is divided into three categories, as shown in Table 2.

Table 2. Clinical Knowledge Base

Data type	Examples	Source	Requirement	Organization method
Patient data	Electronic medical records	HIS/EMR	Authentity and interity	HL7
Scientific knowledge	Disease,symptoms, examination,harmaceuticals, medical technology	Textbooks, authoritative treatment manuals, etc.	Objectivity and authority	ICD-10, pharmacopeia, examination means
Experience knowledge	Guideline, meta-analysis, system evaluation, case reports	Openly published literature	Open publishing and source quality	Literature types, content topics

3.5 KB-CDSS design

KB-CDSS design includes four parts: database construction, functional design, interface design, and platform applications.

1. Database construction: KB-CDSS is based on Wanfang Data IRC technology, which can support the retrieval needs of massive data, multiple fields and multiple languages. KB-CDSS database is divided into the disease base, check base, drug base, guideline base, case report base, evidence-based medicine base, literature citations database, and full-text database, which can be used for different types of applications.
2. Functional design: KB-CDSS functions include knowledge content retrieval, resource navigation, sorting methods, and related recommendations to provide support for different application environments. Knowledge content retrieval provides knowledge content points of different particle sizes and supports precise and fuzzy searches; resource navigation is organized according to the characteristics of content to be easy to read; and sorting is performed according to time, relevance, quality, and content. Related recommendations can recommend the most relevant content according to the current browsing information.
3. Interface technology: KB-CDSS interface technology can support major system types, such as B/S and C/S, and provide return value according to different input parameters, including information on knowledge content, knowledge entry, literature, and clustering results. Data are saved in JSON format.
4. Platform application: KB-CDSS provides different versions depending on the

different application environment. (1) Network version: Doctors generally have the most contact with the Internet. As long as they have access rights, users have access to the necessary knowledge through the network version anytime and anywhere. (2) Mirror version: Most doctors cannot access the Internet at work. The mirror version enables doctors to access knowledge when they cannot access the external network. (3) Client: In order to better support physician workflow and HIS data calls, it can provide more functions that cannot be achieved through the network version. (4) Mobile version: currently, many large hospitals have adopted PDAs or mobile phones as part of their hospital information technology system. The mobile version is quick and easy to use.

4 Discussion and Cases of the Application's Value

The electronic medical record system is an important part of hospital information. A high-quality electronic medical record system must have CDSS functions, so the CDSS plays an important role in hospital information and should be a necessary part of the hospital information system.

A CDSS can significantly improve the quality of medical work, such as by shortening diagnosis time and improving screening accuracy rates.

Currently, the most widely used CDSS is the rational drug use system. The CDSS has a positive effect on reducing the incidence of misdiagnosis, preventing drug incompatibility, and handling medication for special populations.

From the perspective of the medical economy, the CDSS improves doctors' work efficiency, thereby decreasing the number of clinics. Accidents caused by medical errors are reduced, thereby reducing damages to the hospital.

The CDSS also has a significant impact on treatment methods. More and more patients pay close attention to the relevant medical knowledge after treatment and before treatment, and know about them due to the Internet and other means before treatment.

Currently, the Wanfang Data Clinical Diagnosis and Treatment Knowledge Base developed by Wanfang Data has been formally launched and has dozens of official users and dozens of trial users. Feedback from some hospitals is shown in Table 3.

Table 3. KB-CDSS Use Situation of Some Users

User	Version	Advantages	Suggestions
Beijing Grade-III General Hospital	Network version	Simple interface, easy retrieval, rich data types Associated with literature	Extensive knowledge, patient-oriented education Recent progress in improving treatment
Shandong Grade-III Hospital	Client	Easy installation, rich data types, provide expertise and literature	Extensive knowledge, subdivided according to the type of user, sound reasoning mechanism

5 Conclusions and Limitations

Through a study of the theory and application of CDSSs at home and abroad, this paper analyzed the main composition and classification of CDSs and the main problems facing CDSSs, proposed KB-CDSS construction ideas, and described perspectives on KB-CDSS construction ideas, construction principles, clinical workflow analysis, clinical knowledge base construction, and KB-CDSS design. The Wanfang Data Clinical Diagnosis and Treatment Knowledge Base guided by KB-CDSS has been running successfully in some hospitals.

KB-CDSS involves a wide range of theoretical research and design development. This study only describes the basic ideas of KB-CDSS and cannot deeply discuss the clinical workflow, knowledge base construction, and system design. In practice, the content and functionality of the Wanfang Data Clinical Diagnosis and Treatment Knowledge Base need to be improved.

With the development of computer science, evidence-based medicine and hospital information technology, more CDSSs will be applied to electronic medical record systems in hospitals. Doctors' diagnoses are no longer based on personal experience, but they make clinical decisions with the help of CDSSs. KB-CDSS-based Wanfang Data Clinical Diagnosis and Treatment Knowledge Base aims to achieve the purpose of assisting clinical decision-making through continuous improvement and upgrades.

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