Selective Overview on Decision Support Systems: Focus on HealthCare

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Abstract: Decision support systems (DSS) are one type of the applications of information technology that can help clinicians to make right and in time decisions about patients care. The aim of this study is to get familiar with Decision support applications and their effects on healthcare. **Methods:** In this systematic review, articles between 2000 and 2012 which were available as full texts through databases and search engines including PubMED, EBSCO host research, Google scholar and which were also the clinical trials were examined, as well as books in this area that were used as primary sources. **Results:** The findings showed that DSS were applied in five areas in health care, which had significant effect on improving the process of care and the performance of providers. These areas are as follows: disease progress management (15.15%), care and treatment (27.27%), drug prescribing (27.27%), evaluation (18.18%), and prevention (12.12%). **Conclusion:** An overview of various models of DSS and consideration the components which are enhancing the performance of the system, help clinicians to select appropriate system for their operation in order to achieve significant gains such as reducing medical and medication errors, compliance with standard treatment and medication guidelines, reducing costs and ultimately improving the quality of health care.In general, improvement can be seen in three areas: quality of care and patient safety, cost effectiveness and provider's level of knowledge.
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Introduction

Decision making is the process of finding and selecting a series of operations to solve a given problem.[1]Simon considers decision-making process as a spectrum. On one end, there are structured problems which are also called the programmed problems. These are routine problems for which there are standard solutions. In decision-making process there are fairly systematic phases to solve such problems [1].

1- Intelligence phase

During this phase, problem or opportunity is properly identified and defined. The following questions should be considered in identifying the problems for medical decision support:

- Can the solution assist in diagnosing a patient's condition?
- Can the solution assist in determining what the proper drug dosage level should be?
- Can the solution remind the appropriate care giver about the preventative services to be administered to a patient or to patient care related function?
- Can the solution assist in carrying out diagnostic procedure by recommending specific treatments or tests?
- Can the solution assist in carrying out medical procedures by alerts regarding potential adverse events?
- Can the solution assist in providing cost effective medical care by reminding previous orders, results, frequency rule checks, and schedule of treatment or procedure?

2- Design phase

During this phase, the model or sample is provided and the relationship between the variables is determined. Then the validity of the model is evaluated and the criteria of evaluation for the entire process are specified.

3- Choice phase

During this phase the best solution is selected from among the rest.

4- Implementation phase

This phase has recently been added to the Simon's process which shows that the successful implementation of the model leads to solving major problems and the failures in the implementation leads to going back to previous phases [2, 3]. On the other end of the spectrum, there are unstructured problems for which there is no standard solution and none of the three phases of decision-making processes (Intelligence, Design and Choice) are included. There is only human judgment and intuition as a basis for decision making. In the middle of the spectrum, there are semi-structured problems for which only some decision making phases are used to solve and a combination of standard solutions and human judgment are required [2, 3].

Appropriate decision making without information is impossible, because the right information is necessary for each phase and action. Today, decision-making by manual processing of information is difficult due to the following:

1- New and non-traditional methods, because of innovations in technology, improved communications, global market development and use of Internet and electronic commerce, have been increasing.
2- Many decisions must be taken in time pressure in which case, manual processing of information cannot be effective.
3- Due to increased volatility and uncertainty in decision-making environment, to make the right and effective decision one must use complex analysis which requires the use of information technology.
4- There is a need for quick access to data, consulting with experts or decision making meetings [2-9].

Thus, the use of information technology has paved the way for making decisions. Decision support systems (DSS) are one type of the applications of information technology that can help clinicians to make the right decisions in time. The aim of this article is to get familiar with DSS and their applications and effects on healthcare.

Methods

This is a selective review article. Electronic data bases such as Pub Med, EBSCO host, and search engines such as Yahoo and Google Scholar were used in order to search for articles. Also, key terms like ‘decision support system’, ‘clinical decision support system’, and ‘medical decision support system’ were used in the search. Only 85 full texts in English language articles from 2000 to 2012 which were available in Iran (full text) were studied. 33 articles out of 85 related to the implementation of DSS in clinical trials were selected. In addition, we searched in some books as our primary sources on this topic.

Literature Review

A variety of definitions have been proposed for DSS. Keen and Scott-Morton, considered DSS a form of computer-based support for managers who are faced with semi-structured problems. Others introduce DSS as a computer-based interactive system which uses of data and models in order to assist decision makers in terms of solving unstructured problems. But Power, defines DSS as a comprehensive and useful term for a variety of information systems that support decision making.[3-4,10-11] The above definitions can imply that DSS is a computer-based system to solve structured, unstructured and semi structured problems, which with strong collaboration of the users, combines models and data and offers many solutions for decision-makers [3-4,9-10]. Not only there is no general definition for DSS, but also there is no comprehensive classification available. About DSS classification, different authors have proposed different classifications which are presented in table1 [9-12]. About DSS architecture, different authors have provided various components which are presented in Table 2. Considering the cases presented in Table 2, data management which is an important part of the system consists of a database or data warehouse to encompass medical data and is managed by a database management system. User interface subsystem is a communication tool between user and system. The model management, including tables, data necessary to establish rules, and predictive models and protocols provides analytical capabilities to the system. The final subsystem is knowledge management that supports all the other subsystems, can operate independently and, provide the knowledge necessary to solve specific problem [2,7-9,11].

Results

Due to the increasing rate of medical errors, there is a continuing challenge for the clinicians to provide safe and effective care [13]. In this regard, the establishment of clinical guidelines to improve the quality of patient care and reduce medical costs by increasing the cost - benefits can be very effective [14]. These clinical guidelines, pathways and protocols can be available to clinicians in electronic format as DSS [15].

Table1. Types of classifications of DSS based on reviewed studies

Taxonomy Levels	Types of DSS	Definition
User-level	Passive	This system aids the process of decision making, but can't bring out explicit decision suggestions or solutions.
	Active	This system can bring out decision suggestions or solutions.
	Cooperative	This system allows the decision maker to modify, complete, or refine the decision suggestions provided by the system, before sending them back to the system for validation. The system again improves, completes, and refines the suggestions of the decision maker and sends them back to them for validation. The whole process then starts again, until a consolidated solution is generated.
Conceptual-level	Communication-driven DSS	This system emphasizes the use of communications and decision models intended to facilitate the solution of problems by decision makers working together as a group. This is often called group decision support systems.
	Data-driven DSS	This system emphasizes real-time access to large database and manipulation of a time series of internal company data and, sometimes, external data.
	Knowledge-Driven	This system provides specialized problem-solving expertise stored as facts, rules, procedures, or in similar structures.
	Document-driven	This system manages, retrieves, and manipulates unstructured information in a variety of electronic formats.
	Model-driven	This system emphasizes access to and manipulation of a statistical, financial, optimization, or simulation model.
	Intra & inter organizational-driven	These systems are driven by the rapid growth of Internet and other networking technologies such as broadband WAN's, LAN's, WIP, etc. Inter-organization DSS are used to serve companies stakeholders (customers, suppliers, etc.), whereas intra-organization DSS are more directed towards individuals inside the company and specific user groups.
	Web based	This is computerized system that delivers decision support information or tools to a manager or business analyst using a Web browser like Netscape Navigator or Internet Explorer.
	Online Analytical Processing (OLAP)	This is a category of software technology that enables analysts, managers and executives to gain insight into data and view the result in multi dimensional or cube format.
System-level	Enterprise DSS	This is linked to large data warehouses and serves many managers in a company.
	Desktop DSS	This is small system that resides on an individual manager's PC. This is often called single-user DSS.

Table 2. Components and architecture of DSS based on reviewed studies

Components / Authors	Sprague	Power	Hättenschwiler	Marakas	Wager & Tan
DSS Network and Architecture		*			
Knowledge Management Systems			*	*	*
The Model-Base Management System	*	*		*	*
Database Management System	*	*		*	*
User Interface	*	*		*	*
Users			*	*	
A Target System Describing The Majority Of The Preferences			*		
A Specific And Definable Decision Context			*		

As stated in the definition of Clinical DSS: "CDSS is an analyst tool that converts raw data into useful information to help clinicians in better decisions for patients." CDSS can be implemented in

electronic health records and alert clinicians when there is a conflict in care plan or it is necessary to change patient condition substantially based on discovered patterns in clinical data. The types of functions in CDSS for providing alerts are presented in table 5 [13,16,17]. As it clearly shown in table (3), the functions of such systems are diagnosis, interpretation, suggestion and notification most of which are presented as reminder and alert systems.

Table3. Types of functions in CDSS

Types of functions	definition
Diagnosis	Identify the possible diagnosis based on the history, physical, results, and evaluation inputs
Notification	Non conformance, risks, abnormal e vents, and episodes of care
Suggestion	Drug adjustments based o n the recent lab values, trends, and current drug levels current drug levels Interpretation Guidelines as applicable to the current situation – lab test schedule
Interpretation	Guidelines as applicable to the current situation – lab test schedule, protocol development

Table 4. Application areas of DSS based on review studies

Application Areas of DSS	Studies Reviewed	Study Results
Disease process management (15.15%)	-Management of asthma and angina -Guideline implementation for outpatient cardiac rehabilitation -Risk management of CVD in CCU -Management of children with fever without apparent source -Management of renal anemia	-Effectiveness of DSS application in the management of the disease process
Health and care (27.27%)	-Treatment of diabetes mellitus -Treatment of major depression in primary care -Treatment of rheumatology -Telecare -Identification of heparin induced thrombocytopenia -Prevention of pneumonia for patients receiving mechanical ventilation -Provider ordering behavior -Nursing care -Treatment of prostate cancer	-Improvement in the quality of health care
Drug Prescription (27.27%)	-Prescribing behavior for breast cancer patients -Medication dosing for patients with renal insufficiency in the long-term care setting -Reducing prescription of excessive doses -Opioid therapy for chronic non cancer pain -Determining the quality of antimicrobial dosing in intensive care patients with renal insufficiency -Adequacy of venous thromboprophylaxis in acutely ill medical patients -Insulin therapy -Prevention of adverse drug reactions in intensive care patients -Prescribing costs in primary care	-Medication errors reduction -Side and adverse effect reduction -Prescribing costs reduction
Evaluation (18.18%)	-Assessment of suspected breast cancer -Determining the quality of clinical practice - providing a qualitative measure of cardiac care and patient education -Mental health clinical practice guideline -Evidence-based guidelines for blood ordering in primary care -Reducing unnecessarily repeated serology tests in a cardiovascular surgery department -Assessment of chronic urticaria	-Improvement in clinician practice based on recommendations
Prevention (12.12%)	-screening of latent tuberculosis infection -screening of pediatric depression -prevention of venous thromboembolism -screening of osteoporosis	-Increasing in screening rate Reduction in disease infection

Feldstein defines a reminder as "a nonintrusive message regarding something the user should do. With reminders, users can defer follow-up action and usually must take some action to see the entire message. On the other hand, an alert is intrusive, interrupting whatever the user is currently doing without regard for its importance. The user must take immediate action before returning to the previous work." For example, reminding the physician to prescribe a specific drug or specific test for patients and alert the physician to prevent adverse drug events or drug allergy [18]. According to Goud, these messages should be timely, relevant, understandable and without complexity. Thus paying attention to these messages leads to decrease in medication errors and increase in patient safety [19]. Many healthcare organizations have used DSS to improve clinicians practice. In this study, application of DSS in healthcare is divided to five areas including disease progress management (15.15%), care and treatment (27.27%), prescription (27.27%), evaluation (18.18%), and prevention (12.12%). These application areas and the effects of these systems on these areas are shown in table4 [19-51].

Discussion

In this article, at first, the DSS definition, types and components have been provided, since, according to Randell, the users play important role based on understanding of their needs and expectations from these systems. Therefore, an overview of various models of DSS helps users to select appropriate system for their operation in order to better decision making [31]. According to the types of models presented in this paper for the DSS, it is advisable for the clinician to benefit from the knowledge driven DSS in their clinical practices. Because this type of DSS is equipped with database which provides the necessary knowledge for the treatment of diseases using treatment protocols and certain preventive care and helps clinicians in diagnosis, criticism of care plan, planning for treatment, provision of alert and image interpretations [52]. The function of these systems is to adjust the current cases with decision criteria which were derived from statistical analyses performed on previous high volume cases and then decide about [52]. Review of the articles showed that these systems can improve clinical practice and patient outcomes in five application areas including disease process management, care and treatment, drug prescription, evaluation and prevention by performing a series of functions. Roshanov et al. conducted a systematic review on chronic disease management and Sahota et al. conducted a systematic review on acute disease management and both found that the use of CDSS improves the care process but has no effect on patient outcome [53-54]. Jaspers et al. in a systematic review on the impact of CDSS on practitioner performance and patient outcomes concluded that these systems for having reminder and alert system can positively impact healthcare providers' performance but have no effect on patient outcome [55]. Nieuwlaat et al. and Hemens et al. argued that the use of CDSS improves drug prescribing, monitoring and management processes but its effect on patient outcome is not clear [56-57]. In the prevention area, Souza et al. expressed that evidence supports the effectiveness of CDSS for screening and treatment of dyslipidaemia in primary care with less consistent evidence for CDSSs used in screening for cancer and mental health-related conditions, vaccinations, and other preventive care. CDSS effects on patient outcomes, safety, costs of care, and provider satisfaction remain poorly supported [58]. According to the articles reviewed in this study, it can be reported that clinicians using these systems are able to achieve significant gains such as reducing medical and medication errors, compliance with standard treatment and medication guidelines, reducing costs and ultimately improving the quality of health care.

According to Kawamoto et al., CDSS significantly improved clinical practice if features such as automatic provision of decision support as part of clinician workflow, provision of recommendations rather than just assessments, provision of decision support at the time and location of decision making, providing periodic performance feedback, sharing recommendations with patients, and requesting documentation of reasons for not following recommendations in the system are considered [59]. Roshanov et al. believed that to develop an effective CDSS factors such as system design, user interface, local context, implementation strategy, and evaluation of its impact on user satisfaction and workflow, costs, and unintended consequences should be taken into account [60]. Therefore, in designing of the system, one should consider the components which are enhancing the performance of the system. For example, the clinician-oriented interface for proper interactions between patients and clinicians, patient registry, patient encounter scheduler, trial management, clinical decision support, progress note generator, workload and outcomes report generator and translation of written guidelines into actionable, real-time clinical recommendations is the most important, since according to Chang, the outcome of the system is related to the user interface directly. However, because the implementation of such systems is expensive, in addition to the above, the factors such

as organizational commitment and attention, extensive commitment of personnel and the clinician team working as the main users of the system can have a significant impact on the performance of these systems. Also the users should be aware of this fact that these systems can both be a tool for saving clinician time in order to pay attention to the main issues and facilitate having access to references and educational materials such as online information [34,36,61-66]. However, it should be considered that the use of these systems is associated with challenges and their implementation is faced with obstacles such as technical support and issues related to user interface such as patient data coding, interoperability and human factors. As mentioned, patient data coding is one of the challenges in applying CDSS, because all of the patient data must be coded with standard classification correctly in order to be calculated in inference engine. But choosing the correct code is a time consuming machine process that not only do not allow clinicians to focus on the content of the clinical document but also increases the potential loss of the explanatory notes in the text content. To solve this problem, a new clinical data classification based on observation such as SNOMED and UMLS is recommended [67].

Another important challenge is the interoperability that can affect the use of CDSS. To make a recommendation, CDSS must have access to complete and updated patient data. Whereas, clinical computerized systems are now commonly used for management of the patient data, many of these systems do not interact with each other regarding data exchange. Use of data exchange standards such as HL7 and regional networks to exchange health data such as personal health records, which enables loading patient data into a common data repository can address these challenges [67-69].

In addition to the above, there are other factors that make the use of CDSS a challenge. Given that CDSS has a profound effect on patient care, if not applied properly it can cause damage to the quality of patient-physician relationship at the point of care. Since using computer in front of the patient and lack of face to face interaction can be considered an impolite action and at the same time one of the causes of patient resistance. On the other hand, clinicians consider it as a threat to have autonomy in their practice because the new generation of CDSS is equipped with evaluation mechanisms that provide the ability to score clinician. In conclusion, we can say that these features can lead to gradual distortion of the patient's acceptance; therefore solving this problem requires designing user-friendly interfaces, training and informing the users about the benefits of these systems [70].

The study showed that the use of DSS in five application areas including disease management process, care and treatment, drug prescription, evaluation and prevention had significant impact on improvement of the process of care and the performance of clinicians. In general, the effects can be divided to following three groups. First, improving the quality of care and increasing patient safety by reducing medication errors and adverse effects and compliance with evidence-based clinical guidelines. Second, increasing the cost-effectiveness through faster processing of orders, decreasing repetition of lab-test orders, reducing the drug adverse effect events and changing patterns of drug use in the form of prescribing cheaper drugs which have the same effects as generic drugs. And third, promoting the knowledge level through the accessibility of resources, provision of reminders and useful information to optimal decision making with minimum error, Finally, it should be mentioned that in order to increase the effectiveness of these systems, a proper organizational culture be provided and the clinicians as the users of these systems be properly educated.

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