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PROFESSIONAL PAPER

Evaluate the Ability of Clinical Decision Support Systems (CDSSs) to Improve Clinical Practice

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Introduction: Prevalence of new diseases, medical science promotion and increase of referring to health care centers, provide a good situation for medical errors growth. Errors can involve medicines, surgery, diagnosis, equipment, or lab reports. Medical errors can occur anywhere in the health care system: In hospitals, clinics, surgery centers, doctors' offices, nursing homes, pharmacies, and patients' homes. According to the Institute of Medicine (IOM), 98,000 people die every year from preventable medical errors. In 2010 from all referred medical error records to Iran Legal Medicine Organization, 46/5% physician and medical team members were known as delinquent. One of new technologies that can reduce medical errors is clinical decision support systems (CDSSs). **Methods:** This study was unsystematic-review study. The literature was searched on evaluate the "ability of clinical decision support systems to improve clinical practice" with the help of library, books, conference proceedings, data bank, and also searches engines available at Google, Google scholar. For our searches, we employed the following keywords and their combinations: medical error, clinical decision support systems, Computer-Based Clinical Decision Support Systems, information technology, information system, health care quality, computer systems in the searching areas of title, keywords, abstract, and full text. In this study, more than 100 articles and reports were collected and 38 of them were selected based on their relevancy. **Discussion and conclusion:** The CDSSs are computer programs, designed for help to health care careers. These systems as a knowledge-based tool could help health care manager in analyze evaluation, improvement and selection of effective solutions in clinical decisions. Therefore, it has a main role in medical errors reduction. The aim of this study was to express ability of the CDSSs to improve clinical practice. Key words: medical error, clinical decision support systems, CDSS, healthcare quality, information technology, information system

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1. INTRODUCTION

In the past decade, hospitals and healthcare workers have become more familiar with medical errors and the harm they can cause (1). There is a growing public perception that serious medical error is commonplace and largely tolerated by the medical profession (2). An estimated 108,000 people die each year from potentially preventable iatrogenic injury. One in 50 hospitalized patients' experiences a preventable adverse event. Yet no matter how well trained and how careful health care providers are, individuals will make mistakes because they are human (3).

Newspaper and television stories of catastrophic injuries occurring at the hands of clinicians spotlight the problem of medical error but provide little insight into its nature or magnitude. 1 Clinicians, patients, and policy makers may underestimate the magnitude of risk and the extent of harm. We review the epidemiology of medical error, concentrating primarily on the prevalence and consequences of error, which types are most common, which clinicians make errors, and the risk factors that increase the likelihood of injury from error (4). Progress has been slower in translating policy into action at the level of the frontline clinician. The recent worldwide recession and soaring healthcare budgets have resulted in increased pressure on healthcare workers to do more with less (1). A clinical decision support system (CDSS) is an application that analyzes data to help healthcare providers make clinical decisions. A CDSS is an adaptation of the decision support system commonly used to support business management. Physicians, nurses and other health care professionals use a CDSS to prepare a diagnosis and to review the diagnosis as a means of improving the final result. Data mining may be conducted to examine the patient's medical history in conjunction with relevant clinical research. Such analysis can help predict potential events, which can range from drug interactions to disease symptoms.

There are two main types of clinical decision support systems. One type of CDSS, which uses a knowledge base, applies rules to patient data using an inference engine and displays the results to the end user. Systems without a knowledge base, on the other hand,

rely on machine learning to analyze clinical data (5). Rates of medical errors are increasing day by day. One of new technologies that can reduce medical errors is clinical decision support systems. The objective of this review was to non-systematically review the effects of the CDSS on physician performance and patient outcomes and evaluate the ability of clinical decision support systems (CDSSs) to improve clinical practice.

2. METHODS

This study was non-systematic reviewed which the literature on the CDSS applications in healthcare was based on a formal research framework. We used a sub-systematic method, which was divided into three phases: literature collection, assessing, and selection. Researchers identified studies which denoted advantages and disadvantages of applying the CDSS in healthcare centers. The literature was searched on evaluate the "ability of clinical decision support systems to improve clinical practice" with the help of library, books, conference proceedings, data bank, and also searches engines available at Google, Google scholar. This study in June, July and June 2012 was performed. For our searches, we employed the following keywords and their combinations: medical error, clinical decision support systems, Computer-Based Clinical Decision Support Systems, information technology, information system, healthcare, quality, and computer systems in the searching areas of title, keywords or abstract. More than 100 articles were collected and assessed 38 of them were selected based on their relevancy. The CDSS has been applied in a variety of healthcare practices. We investigated a total of 38 research papers to identify the cutting-edge hospital. The last phase followed our proposed research framework and conducted detail analysis with regard to the literature. We proposed some useful suggestions and implications [e.g., the most popular application, the perceived benefits, critical barriers and limitations] for researchers in this area. We first identified the existing problems and challenges faced by healthcare. Then we studied how the CDSS was applied in healthcare area to solve or partially solve these barriers. By analyzing the research prototypes, pilot studies, and case studies in our collected literature, we identified the benefits and barriers of the CDSS adoption in healthcare. These implications can be used to guide future research in this field.

3. RESULTS

The IOM reports on medical errors are among the leading causes of death in the United States. In its highly publicized report, the Institute of Medicine estimates that between 44,000 and 98,000 Americans die as a result of medical errors each year, with the majority of these errors being preventable (6, 7 , 8). Examples of decision support systems (DSSs) are the CDSS for diagnosing diseases or prescribing medicine and Knowledge Management Systems (KMSs) for financial management and marketing analysis. CDSS is defined as: 'providing clinicians or patients with computer-generated clinical knowledge and patient-related information, intelligently filtered or presented at appropriate times, to enhance patient care (9).

Studies on the CDSSs show that these systems have a positive impact on treatment outputs and health care process. Medical errors reduction, improvement of health care proficiency via reduction in casts, health care quality improvement is main the CDSS premiums (10).

The DSSs are generally integrated with a data warehouse, which is a comprehensive data repository of decision-oriented information (11). In health management systems, information has a special role in planning, evaluation, training, legal aspects and research (12). In fact, the fist distinction between developed and developing countries, are the production, application and utilization of information (13, 14) that one of the important part of the CDSSs is information base. Since the DSSs can be more easily developed if there is sound information technology (IT) infrastructure such as data warehouse or electronic medical records (EMRs), the increasing adoption of such infrastructure by hospitals necessitates an examination of the KMSs adoption (11).

Recent research has shown that health care delivered in industrialized nations often falls short of optimal, evidence based care. A nationwide audit assessing 439 quality indicators found that US adults receive only about half of recommended care (15). Similarly a retrospective analysis at two London hospitals found that 11% of admitted patients experienced adverse events, of which 48% were judged to be preventable and of which 8% led to death (16).

To address these deficiencies in care, healthcare organizations are increasingly turning to the CDSSs, which provide clinicians with patient-specific assessments or recommendations to aid clinical decision making. Such systems have been shown to improve prescribing practices, reduce serious medication errors, enhance the delivery of preventive care services, and improve adherence to recommended care standards. Compared with other approaches to improve practice, these systems have also generally been shown to be more effective and more likely to result in lasting improvements in clinical practice. The CDSSs do not always improve clinical practice, however (15).

The CDSSs appeared to perform better in institutional compared to ambulatory settings and when decision support was initiated automatically by the system as opposed to user initiation. The CDSSs implemented with other strategies such as education were no more successful in improving prescribing than stand alone interventions. Cardiovascular disease was the most studied clinical target but few studies demonstrated significant improvements on the majority of prescribing outcomes (17). In contrast to clinical reference material, such as continuously updated online journals and medical texts, computerized the CDSSs directly assist the clinician in making decisions about a specific patient. The DSSs do not need to be sophisticated to have significant impact. For example, simple dose-range checking for medications (such as opiates and insulin), drug-drug interaction checking, and drug-allergy checking are conceptually straightforward but can catch a critical source of human error that no amount of personal vigilance will entirely eliminate. The most complex decision support systems attempt to aid clinical diagnosis. The applica-

tion of artificial intelligence to medicine has a long history; however, most diagnostic expert systems have been standalone, requiring effort by the clinician outside of their normal workflow and have thus seen limited clinical implementation (18).

Of the 7 studies for evaluating isolated CDSSs, 3 demonstrated statistically significant improvements in antibiotic-associated medication errors or adverse drug events and an improvement in theophylline-associated medication errors. The remaining 3 studies had no significant results. Use of the CDSSs can substantially reduce medication error rates (19).

In a study titled Effects of Computer-Based CDSSs on Physician Performance and Patient Outcomes: Results showed that published studies of the CDSSs are increasing rapidly, and their quality is improving. The CDSSs can enhance clinical performance for drug dosing, preventive care, and other aspects of medical care, but not convincingly for diagnosis. The effects of the CDSSs on patient outcomes have been insufficiently studied (20).

Studies had to evaluate the ability of DSSs to improve clinical practice showed that the CDSSs significantly improved clinical practice in 68% of trials. Univariate analyses revealed that, for five of the system features, interventions possessing the feature were significantly more likely to improve clinical practice than interventions lacking the feature. Multiple logistic regression analysis identified four features as independent predictors of improved clinical practice: automatic provision of decision support as part of clinician workflow ($P < 0.00001$), provision of recommendations rather than just assessments ($P = 0.0187$), provision of decision support at the time and location of decision making ($P = 0.0263$), and computer based decision support ($P = 0.0294$). Of 32 systems possessing all four features, 30 (94%) significantly improved clinical practice. Furthermore, direct experimental justification was found for providing periodic performance feedback, sharing recommendations with patients, and requesting documentation of reasons for not following recommendations (15). The CDSSs can be used as knowledge-based tools in analyzing, evaluating, improving and selecting effective solution when clinical decision by healthcare providers (21, 21 , 22, 23).

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Computer systems have long been promoted for their potential to improve the quality of health care, including their use to support clinical decisions. Computer-based DSSs provide additional assistance. They can synthesize and integrate patient-specific information, perform complex evaluations, and present the results to clinicians in a timely fashion. Examples include the CDSSs designed to recommend appropriate drug doses, to provide immunization reminders, or to diagnose the cause of a patient's chest pain. As with any innovative health care intervention, however, these systems should be rigorously evaluated before widespread introduction into clinical practice. The various stages in this assessment process have been described by Wyatt and Spiegelhalter, including using controlled trials to test the effects on clinical behavior and patient outcomes.

Hunt et al noted, "in addition to 28 studies previously reviewed, we identified 40 new studies that met our selection criteria and included sufficient results to be able to determine whether using the CDSS had affected health care practitioner behavior or patient outcomes. Several additional trials met our inclusion criteria but included insufficient results to determine the effect of using the CDSS. We also identified 9 review articles that discussed decision support systems. Four of these were narrative, non systematic reviews, including 2 that discussed the role of decision support in health care in general and 2 that focused on specific aspects of decision support, including diagnostic aid systems and cancer prevention systems. The remaining 5 articles were systematic reviews. These included 2 prior publications by our group and articles by Austin et al., Balas et al., and Shea et al., and Austin et al. completed a meta-analysis in 1994 of trials that assessed the effects of computer-based reminder systems on cervical cancer screening and tetanus immunization. This demonstrated a significant beneficial impact for both of these maneuvers. Balas et al systematically reviewed the evidence from randomized controlled trials assessing numerous clinical information systems. They also reviewed the area of patient education. Their review demonstrated that reminder systems and drug dosing systems can improve health care practitioner performance. The meta-analysis by Shea and colleagues evaluated computer-based reminder systems for preventive care. They found benefits for vaccinations, breast cancer screening, colorectal cancer screening, and cardiovascular risk reduction but not for cervical cancer screening." (20).

They added, "Of the total of 68 included trials, 15 (22%) tested the CDSSs designed to assist with dosing estimations for potentially toxic drugs, 5 (7.0%) evaluated diagnostic aids, 19 (28%) assessed systems for preventive care, and 29 (43%) tested programs for other aspects of medical care. Almost all of these studies evaluated effects on clinician performance, but only 14 assessed patient outcomes. Of the 65 studies that evaluated the effect of using a CDSS on clinician behavior, 43 (66%) found at least some benefit. These included 9 (60%) of 15 studies on drug dosing systems, 1 (20%) of 5 studies evaluating diagnostic aids, 14 (74%) of 19 preventive care systems, and 19 (73%) of 26 studies assessing the CDSSs for other medical care. Only 6 (43%) of the 14 studies that evaluated the effects on patient outcomes documented a benefit. However, 5 (62%) of the 8 trials that found no benefit for patient outcomes had a power of less than 80% to detect a moderate and clinically important improvement" (20). Together, these 3 interventions—ward-based clinical pharmacists; computerized provider order entry (CPOE) with CDSSs; and improved communication between physicians, pharmacists, and nurses—could potentially have prevented 98.5% of errors (24).

In other study patients in the computer based clinical decision support system and chart only groups were no more likely to have cardiovascular risk reduced to below 10% than patients receiving usual care (25). David and his colleagues showed in a study stating that while evidence-based medicine has increasingly broad-based support in health care, it remains difficult to get physicians to actually practice it. Across most domains in medicine, practice has lagged behind knowledge by at least several years. The authors believe that the key tools for closing this gap will be information systems that provide decision support to users at the time they make decisions, which should result in improved quality of care. Furthermore, providers make many errors, and clinical decision support can be useful for finding and preventing such errors (26).

The DSSs significantly improved clinical practice in 68% of trials. Univariate analyses revealed that, for five of the system features, interventions possessing the feature were significantly more likely to improve clinical practice than interventions lacking the feature. Multiple logistic regression analysis identified four features as independent predictors of improved clinical practice: automatic provision of decision support as part of clinician workflow ($P < 0.00001$), provision of recommendations rather than just assessments ($P = 0.0187$), provision of decision support at the time and location of decision making ($P = 0.0263$), and computer based decision support ($P = 0.0294$). Of 32 systems possessing all four features, 30 (94%) significantly improved clinical practice. Furthermore, direct experimental justification was found for providing periodic performance feedback, sharing recommendations with patients, and requesting documentation of reasons for not following recommendations. Several features were closely correlated with decision support systems' ability to improve patient care significantly. Clinicians and other stakeholders should implement CDSSs that incorporate these features whenever feasible and appropriate (15). A systematic review of the impact of the CDSSs has demonstrated statistically significant improvements in antibiotic-associated Medication errors (MEs) or adverse drug events and an improvement in theophylline-associated the MEs, while several studies have shown non-significant results (27).

Representatives of 34 community hospitals, each of which had over 5 years experience with CPOE, were interviewed to identify standard practices related to the CDS showed that this broad sample of community hospitals had robust levels of CDS despite their small size and the independent nature of many of their physician staff members. The hospitals uniformly used medication alerts and order sets, had sophisticated governance procedures for the CDS, and employed staff to customize the CDS. The level of customization needed for most CDS before implementation was greater than expected. Customization requires skilled individuals who represent an emerging manpower need at this type of hospital.

These results bode well for robust diffusion of the CDS to similar hospitals in the process of adopting CDS and suggest that national policies to promote CDS use may be successful (28).

Thirty-six studies met our inclusion criteria for acute medical care. The CCDSS improved process of care in 63% (22/35) of studies, including 64% (9/14) of medication dosing assistants, 82% (9/11) of management assistants using alerts/reminders, 38% (3/8) of management assistants using guidelines/algorithms, and 67% (2/3) of diagnostic assistants. Twenty studies evaluated patient outcomes, of which three (15%) reported improvements, all of which were medication dosing assistants.

Conclusions that study showed that the majority of CDSSs demonstrated improvements in process of care but patient outcomes were less likely to be evaluated and far less likely to show positive results. CDSSs for acute medical care have not matured to degree that clinical decision makers should embrace the technology for clinical application (29).

Characteristics	Category	Adaption CDSS		Total	χ^2	P-Value
		YES	NO			
Hospital Size	Less than 801	2(15.38)	11(35.48)	13(29.55)	1.777	0.182
	Greater than 800	11(84.62)	20(64.52)	31(70.45)		
Ownership	Foundation	3(23.08)	4(12.90)	7(15.91)		
	University	8(61.54)	24(77.42)	32(72.73)	1.176	0.555
	Public	2(15.38)	3(9.68)	5(11.36)		
Location	Seoul	7(35.85)	9(29.03)	16(36.36)		
	Metropolitan	2(15.38)	11(35.48)	13(29.55)	2.862	0.239
	Province	4(30.77)	11(35.48)	15(34.09)		
Top management support	Yes	11(91.67)	27(90.00)	16(38.10)	0.037	0.868
	No	1(8.33)	3(10.00)	4(9.52)		
Standardization	Yes	8(66.67)	8(26.67)	16(38.10)	5.815	0.015
	No	4(33.33)	22(73.33)	26(61.90)		

Table 1. Characteristics of Clinical Decision Support System (CDSS) adoption

In study that data taken from the 2010 survey on the HIS status and management issues for 44 tertiary hospitals and 2009 survey on hospital performance appraisal were used, Conclusion showed that Hospital size and top management support were significantly associated with the adoption of EMR. Unlike the EMR results, however, only the standardization characteristic was significantly associated with CDSS adoption. Both EMR and CDSS were associated with the improvement of hospital performance (11).

As seen in Table 1, only standardization was significantly associated with the CDSSs adoption. Standardization refers to the hospitals that had adopted standard terminology to develop EMR or CDSS. Eight hospitals (66.7%) developed CDSS by using standard terminologies. Adoption of CDSS were higher for hospitals with over 800 beds, foundation-owned hospitals, public hospitals, and hospitals located in Seoul than the hospitals that did not adopt the CDSSs (11). EMR and CDSS influenced the improvement of hospital performances. The CDSSs improve patient safety and quality of clinical services (30). Florez-Arango et al in their article that entitled "Performance factors of mobile rich media job aids for community health workers" said that reported of an increased adherence to guidelines by healthcare workers using the CDSS's on mobile devices in a controlled experimental setting (31). And in another article Bates and Partners in their article that entitled "Effect of computerized physician order entry and a team intervention on prevention of se-

rious medication errors" said the CDSSs also reduced serious medication error rates by 55% in one study (32).

Significant improvements in health care could be achieved if computer advice improved health outcomes and could be implemented in routine practice in a cost effective fashion. Computerized advice for drug dosage has some benefits: it increased the initial dose of drug, increased serum drug concentrations and led to a more rapid therapeutic control. It also reduced the risk of toxic drug levels and the length of time spent in the hospital. However, it had no effect on adverse reactions. In addition, there was no evidence to suggest that some decision support technical features (such as its integration into a computer physician order entry system) or aspects of organization of care (such as the setting) could optimize the effect of computerized advice (33). This document comprises an AMIA Board of Directors approved White Paper that presents a road map for national action on clinical decision support (34).

Hug and Partners in their article that entitled "Adverse drug event rates in six community hospitals and the potential impact of computerized physician order entry for prevention" said There is some evidence that the use of the CDS could have a profound impact on care offered by community hospitals: a recent study of six community hospitals found that these hospitals actually had higher adverse drug event rates than academic hospitals and that a higher proportion appeared to be potentially preventable using the CDS (35). Reminders are more effective than feedback in modifying physician behavior related to medication management. Patient-directed reminders can improve medication adherence (36).

Many CDSSs improve practitioner performance (37). In a study entitled Clinical Decision Support Systems for the Practice of Evidence-based Medicine, indicated that the recommendations fall into five broad areas-capture literature-based and practice-based evidence in machine-interpretable knowledge bases; develop maintainable technical and methodological foundations for computer-based decision support; evaluate the clinical effects and costs of clinical decision support systems and the ways clinical decision support systems affect and are affected by professional and organizational practices; identify and disseminate best practices for work flow–sensitive implementations of clinical decision support systems; and establish public policies that provide incentives for implementing clinical decision support systems to improve health care quality. Although the promise of clinical decision support system–facilitated evidence-based medicine is strong, substantial work remains to be done to realize the potential benefits (38). The use of CDSSs is expected to increase in light of the HITECH Act, which stipulates that health care providers must demonstrate the meaningful use of health IT by 2015 or face reduced Medicare reimbursements beginning in 2016. Under meaningful use, providers must implement one clinical decision support rule, including diagnostic test ordering, as well as the ability to track compliance with that rule. That rule, furthermore, should apply to a specialty or high-priority condition (5).

4. CONCLUSIONS

Use of last medical methods for make valid diagnosis and selection of best treatment methods by physician are same case in clinical governance. Finally, our studies showed that the rate of medical errors has increased and clinical decision support systems are one of the best systems to prevent and reduce medical errors. This system could help health care manager in evaluation, analyze, improvement and selection of effective solutions in clinical decisions. Therefore the CDSSs have a main role in medical errors reduction and that have high ability to improve clinical practice.

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