Case Report

Role of clinical decision support systems in improving clinical practice

Abstract

This paper examines the role of clinical decision support systems (CDSS) as a critical and increasingly prevalent tool in improving clinical practice. Using findings from previously published reference papers, books and other related studies, the paper demonstrates how clinical decision support systems are repeatedly being used in clinical practice to enhance quality of care, improve safety, reduce healthcare costs and heighten efficiency. Although findings from the reference papers, books and studies vary in how clinical decision support systems can advance clinical practice, they strongly identify improvements made in clinical practice as they relate to patient safety, medication errors, clinical workflows and processes, diagnostic processes, compliance with regulatory guidelines, disease management, patient outcomes, genomic and personalized medicine and cost of care.

Keywords: clinical decision support systems, clinical practice, findings, healthcare

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Abbreviations: CDSS, clinical decision support systems; CCDSS, computerized clinical decision support systems; ADEs, adverse drug events ; NCI, national cancer institute; WHO, world health organization

Introduction

The healthcare industry has been making significant changes to the way heath care services are delivered to the American public. One important change is the increasing use of new technologies within healthcare facilities across the country to provide high-quality, safer and cheaper healthcare services. Healthcare organizations are implementing new information systems and technologies that combine the use of computers for storing patients' data, sharing information and giving advice to clinicians in diagnosing patients, ordering medications and solving other clinical problems. Hence, those systems designed to tackle the task of supporting the decisions of clinicians are deemed increasingly important and require very advanced methodological approaches and processes. Such systems can be used in providing alerts, critiques, suggestions and feedback on quality of care provided to patients. This paper undertakes a review of previously published articles, books and studies that clearly demonstrated the valuable impact of clinical decision support systems in improving clinical practice.

Background

The application of CDSS's into clinical practice is far from being a new quest. An attempt to get CDSS's to play an active role in solving clinical problems and decision making began as far back as the early 1950s. Greenes[1] wrote, "A large number of computer-based clinical decision aids have been developed and their usefulness evaluated over the past 40+years. Many of these have involved simple types of decision support like recognizing that a laboratory test result is out of normal range, or that a medication being ordered has a dangerous interaction with another one that a patient is taking, or determining that a patient is now due for a flu shot". Accordingly, Shortliffe[2] recognized the historical aspect of CDSS's and advanced, "Since the earliest days of computers, health professionals have anticipated the time when machines would assist them in the diagnostic process. The first articles dealing with this possibility appeared in the late 1950s and experimental prototypes appeared within a few years.

Areas of improvement in clinical practice

Patient safety

This section of the paper provides a review of the reference papers mentioned earlier to depict areas of clinical practice in which CDSS's have been proven to offer significant improvements. Hence, Pearson et al.,[3] in the study Do computerized clinical decision support systems for prescribing change practice? A systematic review of the literature (1990-2007),presented findings of related studies that depict the significance of CDSS's in enhancing patient safety and write, The effective interventions implemented after drug selection had taken place all used system-initiated advice to flag key safety issues (such as alerting providers to high severity drug interactions, contraindications with other medications and cautions against prescribing particular medications for the elderly) or provided quality use of medicine messages (such as alterations to durations of therapy and/or form of prescribed drugs). This supports our hypothesis that it is easier to influence practice in relation to fine-tuning therapy rather than attempting to influence initial therapeutic choices. We also found some evidence to support the benefits of CDSS's in increasing the laboratory testing rates for patients on long-term therapy including cardiovascular and respiratory medicines". In view of that, Jao et al.,[4] presented a survey of 800 healthcare practitioners in which 80% of participants agree to and accept that CDSS's can significantly increase patient safety.

Medical errors

Generally, healthcare organizations must deal with critical activities in reducing medication errors such as preventing those errors, making them detectable and alleviating their effects. Various studies have shown that CDSS's can be an essential tool in reducing medication errors by assisting clinicians in preventing adverse drug reactions,

reducing inappropriate drug dosing and reinforcing the use of effective prophylactic measures. The Institute of Medicine (1999) reported that between 44,000 to 98,000 patients die in the United States due to preventable mistakes and CDSS's can be one of the tools to prevent such errors. In that context, Jao et al.,[4] illustrated the importance of CDSS's in reducing medication errors and argued that "Improvement and automation in a CDSS can assist clinicians making errors visible and augmenting error prevention. A CDSS provides several modes of decision support, including alerts, reminders, advice, critiques and suggestions for improved care. In this way, CDSS's are able to decrease error rates by influencing physician behavior, improving clinical therapy". Moreover, in Effects of Computerized Physician Order Entry and Clinical Decision Support Systems on Medication Safety: A Systematic Review, Kaushal et al.,[5] published the findings of other studies that demonstrated how the implementation of CDSS's can statistically significant reduce antibiotic-associated medication errors or adverse drug events and theophylline-associated medication errors. Also, they compiled findings of related studies that portray CDSS's as "promising interventions that target the ordering stage of medications, where most medication errors and preventable ADEs occur. Basic clinical decision support provides computerized advice regarding drug doses, routes and frequencies and more sophisticated CDSS's can perform drug allergy checks, drug–laboratory value checks and drug-drug interaction checks and can provide reminders about corollary orders (eg, prompting the user to order glucose checks after ordering insulin) or drug guidelines". Following, Kaushal et al.,[5] listed findings from multiple studies that assess the impact of CDSS's in reducing medication errors as shown in the Table 1.

Table 1 Findings of studies on the impact of CDSS's in reducing medication errors

Study description	Study design	Study outcomes	Results
Impact of faculty and physician reminders(using CPOE) on corollary orders for 2181 adult inpatients in a general medical ward at a public teaching hospital affiliated with the Indiana University School of Medicine	Level 1(RCT with physicians randomized to receive reminders or not)	Level 2 and 3(Errors of emission in corollary orders)	25% Improvement in ordering of corollary medications by faculty and residents(P<.001)
CPOE with CDSSs for 6771 adult inpatients on medical surgical and intensive care wards at 6WH, a tertiary care center affiliated with Harvard University	Levels 2 and 3(2 study designs)	Level 1(ADE rates) and level 2(serious medication errors)	55% Decrease in non intercepted serious medication errors(P=.37) and 17% decrease in preventable ADEs(P=.37)
CPOE with CDSSs for 1817 adult inpatients in 3 medical units at BWH	Level 3(retrospective time series)	Level 1(ADEs) and level 2(main outcome measure was medication errors)	81% Decrease in medication errors(P<.001) and 86% decrease in nonintercepted serious medication errors(P<.001)
CPOE with CDSSs for all adult inpatients at BWH	Level 3(retrospective before-after analysis)	Levels 2 and 3(changes in 5 prescribing practices)	Improvement in 5 prescribing practices(P<.001 for each of the 5 comparisons)
CPOE with CDSSs to adjust drug dose and frequency in 7490 adult in patients with renal insufficiency at BWH	Level 1(RCT with a Crossover design)	Level 2(inappropriate drug dose and frequency)	13% Decrease in inappropriate dose(P<.001) and 24% decrease in inappropriate frequency(P<.001)

ADE, adverse drug event; BWH, brigham and women's hospital; RCT, randomizes controlled trial

Three of the studies assessing isolated CDSS's evaluated computerized antibiotic drug advice and demonstrated lower rates of toxic levels, improved pathogen susceptibility and a decreased anti-infective drug–associated ADE rate. Burton evaluated a computerized amino glycoside dosing program and demonstrated lower rates of toxic levels in intervention patients, but the results were not statistically significant (P=.40). Evans demonstrated a 17% greater pathogen susceptibility to an antibiotic drug regimen suggested by a computer consultant vs a physician (P<.001). In another study, reported a 70% decrease in ADEs caused by anti-infective agents through use of a computer-based anti-infective drug management program (P=.02). Two other studies evaluated theophylline dosing. Casner demonstrated no difference in rates of toxic serum levels. In contrast, Hurley demonstrated significantly lower rates of toxic levels in intervention patients (18.9%) than in control patients (37.8%) (P=.04).

The final 2 studies evaluated anticoagulation agents. Evaluation of a heparin dosing system demonstrated lower rates of bleeding events in intervention patients (4.2%) vs control patients (7.7%), but without statistical significance (P=.6). 44 Similarly, evaluation of a warfarin (Coumadin) dosing program demonstrated lower rates of bleeding complications (0% vs 8%) and over anticoagulation rates (5% vs 17%), but neither result was statistically significant (P=.11).

Diagnostic and workflow processes

In addition to improving safety and reducing medication errors, various studies have shown that CDSS's are very adequate in ameliorating diagnostic and workflow processes in healthcare. It has been repeatedly agreed upon that CDSS's have a great potential to decrease medical diagnostic errors and enhance quality of care in general. In a review of 55 trials, Roshanov agreed that 87% (n=48)

reveal that CDSS's can impact the process of care and 52% (n=25) of those demonstrate statistically significant improvements. Presently, they wrote computerized clinical decision support systems (CCDSS's) may help practitioners meet the requirements of chronic care. These systems analyze a patient's characteristics to provide tailored recommendations for diagnosis. In terms, Jao et al.,[4] corroborated the positive impact of CDSS's on diagnostic and workflow processes and claimed. It is critical to design a useful CDSS so that it improves a clinician's workflow, it provides satisfactory system performance and results in acceptable system reliability. Moreover, organizational factors such as the leadership support, strong clinician champions and financial support play a role in the success of CDSS implementation"

Disease management

CDSS's have been intensively used for advancements in many areas of clinical practice. Lately, healthcare organizations have applied CDSS's applications into disease management to better control various diseases and enhance quality of care in general. Effective CDSS's can also be critical in creating a disease management plan after a particular disease is discovered. In fact, Rohanov, through the results of a study intended to determine the impact of CDSS's in disease management concluded the following "CCDSS's can improve chronic disease management processes and in some cases patient outcomes. Recent trials in diabetes care show the most promising results. The mechanisms behind systems success or failure remain understudied. Future trials with clear descriptions of system design local context implementation strategy, costs, adverse outcomes, user satisfaction and impact on user workflow will better inform CCDSS development and decisions about local implementation. Furthermore, they conducted a systematic review of many trials to validate that "A small majority (just over half) of CCDSS's improved care processes in chronic disease management and some improved patient health". Finally, other experts have published research studies that made the case for a successful application of CDSS's into disease management. Notably, Pearson et al.,[3] examined the influence of CDSS's on managing diseases and stated. However, CDSS's have become increasingly sophisticated by matching patient characteristics with computerized knowledge bases and using algorithms to generate patient-specific assessments or treatment recommendations.

Patient outcomes

Earlier we discussed the increasing use of CDSS's in improving disease management nonetheless CDSS's can also help healthcare practitioners in their quest of reaching better patient outcomes. To do so such systems must be used at the point of care in order to help clinicians make decisions that positively impact outcomes of care. Here again, many studies have shown that CDSS's can help in improving patient outcomes such as survival rate, length of stay and cost of care Jao et al.[4] Another study by Roshanov provided statistical data in showing the effectiveness of CDSS's in improving patient outcomes. This survey presented a review of 40 related studies to conclude that "Of these 40 studies, 37 measured processes of care of which 62% (23) showed an improvement and 27 measured patient outcomes of which 19% (5) showed an improvement". As seen in the Table 2. Pearson illustrated results of studies that show the use of CDSS's in improving at least 1 positive outcome.

Table 2 Studies reporting at least one positive outcome and ≥ 50% significant outcomes in favor of CDSS

	Before drug selection(N=26) N/N(%)		After drug selection(N=12) N/N(%)		Monitoring(N=23) N/N(%)	
	At least one positive outcome	≥50% Statistically significant outcomes	At least one positive outcome	≥50% Statistically significant outcomes	At least one positive outcome	≥50% Statistically significant outcomes
Overall	24/26(92)	12/26(46)	12/12(100)	7/12(58)	18/23(78)	8/23(35)
Initiation Of CDSS						
System	19/20(95)	12/20(60)	12/12(100)	7/12(58)	9/11(82)	6/11(55)
User	2/3(67)	0/3(0)	NA	NA	9/11(82)	2/11(18)
Mixed/Unclear	3/3(100)	0/3(0)	NA	NA	0/1(0)	0/1(0)
Clinical Setting						
Institutional	5/5(100)	3/5(60)	5/5(100)	4/5(80)	6/7(86)	3/7(43)
Ambulatory Care	18/20(90)	8/20(40)	7/7(100)	3/7(43)	10/14(71)	4/14(29)
Both	1/1(100)	1/1(100)	NA	NA	2/2(100)	1/2(50)
Mode Of Delivery						
Multi-Faceted	13/15(87)	5/15(33)	NA	NA	5/7(71)	2/7(29)
CDSS Only	11/11(100)	7/11(64)	12/12(100)	7/12(58)	13/16(81)	6/16(38)
Clinical Area						
Cardiovascular	13/16(81)	4/16(25)	1/1(100)	0/1(0)	2/3(67)	1/3(33)
Antibiotics	2/2(100)	1/2(50)	6/6(100)	4/6(67)	1/1(100)	0/1(0)

Table Continued..

	Before drug selection(N=26) N/N(%)		After drug selection(N=12) N/N(%)		Monitoring(N=23) N/N(%)	
	At least one positive outcome	≥50% Statistically significant outcomes	At least one positive outcome	≥50% Statistically significant outcomes	At least one positive outcome	≥50% Statistically significant outcomes
Clinical Area						
Vaccinations	8/9(89)	5/9(56)	NA	NA	NA	NA
Respiratory	1/2(50)	0/2(0)	3/3(100)	1/3(33)	2/5(40)	1/5(20)
Anticoagulants	3/3(100)	2/3(67)	NA	NA	9/9(100)	2/9(22)
Elderly	NA	NA	4/4(100)	2/4(50)	0/1(0)	0/1(0)
Osteoporosis	2/2(100)	1/2(50)	NA	NA	NA	NA
Other	3/4(75)a	3/4(75)a	2/2(100)b	2/2(100)b	5/6(83)c	4/6(67)c

Cost of care

In addition to those previously cited improvements in clinical practice that can be attributed to the implementation of CDSS's in the healthcare setting, CDSS's are also known to allow significant reduction of cost of care. It has been well documented and proven that CDSS's can lower cost of care by alerting clinicians to potentially duplicative testing. According to a report on CDSS's prepared and published by the Agency for Healthcare Research and Quality,[6] CDSS's can be particularly successful in reducing costs of care that often result from adverse drug events (ADEs). Thus, the report addressed how CDSS's can lead to cost reduction in

Clinical practice: The main focus of studies that looked at outcomes other than health care quality has been the effect of CDS on health care costs, with an emphasis on lowering costs by reducing adverse drug events (ADEs). Because ADEs have been shown to increase costs and because CDS can detect and potentially prevent ADEs it is assumed that CDS can reduce health care costs by helping to reduce ADEs. There is some literature to show that CDS can reduce costs, although many of these analyses have used cost data related to known costs of ADEs (e.g., costs of increased length of stay, treatments, etc., that occur if a patient has an ADE), the costs of inappropriate prescriptions, or the costs of failing to prescribe antibiotics prior to surgery (e.g., costs similar to those used to determine ADE costs if a patient acquires an infection). These studies have then used their own data or the literature on the demonstrated effects of CDS to determine the extent of reduction of these adverse events (i.e., ADEs or infections). From these data they estimated the cost savings. Most studies have either used modeling techniques based on the literature or have examined costs prior to and after implementation of CDS, rather than a direct assessment of actual cost savings that can clearly be attributed to the use of CDS.

Personalized medicine

Finally, with the advent of personalized medicine as an emerging trend that utilizes a patient's genes, proteins and biomarkers to determine medical treatment and diagnosis specific to that patient, various studies have conveyed the need for using CDSS's to help in the development of personalized medicine from research to practice. The National Cancer Institute (NCI)[7] defines personalized medicine as "A form of medicine that uses information about a person's genes, proteins and environment to prevent, diagnose and treat disease" (NCI). Accordingly, Kawamoto et al.,[8] in the study, A National

Clinical Decision Support Infrastructure to Enable the Widespread and Consistent Practice of Genomic and Personalized Medicine, called for the implementation of a nation decision system application as a vital constraint for genomic-based medicine known as personalized medicine. They understood the importance of CDSS's in personalized medicine and write: "Critical to the achievement of more efficient and effective healthcare enabled by genomics is the establishment of a robust, nationwide clinical decision support infrastructure that assists clinicians in their use of genomic assays to guide disease prevention, diagnosis and therapy. Requisite components of this infrastructure include the standardized representation of genomic and non-genomic patient data across health information systems; centrally managed repositories of computer-processable medical knowledge; and standardized approaches for applying these knowledge resources against patient data to generate and deliver patient-specific care recommendations".[8] Additionally, in another paper Personalized Medicine and the Need for Decision Support Systems, Denecke et al.,[9] introduced a framework for the application of CDSS's into personalized medicine as a requirement for success. Hence, they noted, personalized medicine is constituted by multidisciplinary integration of human and medical genetics, pharmaceutics, biomaterial banking, clinical research and patient data management. Thus, CDS for personalized medicine need to combine approaches taken from the bioinformatics' domain with expertise and experience in the field of traditional CDS. Areas pioneering in personalized medicine, e.g. therapy management of mamma carcinoma should be selected as focused and paradigmatic applications for CDS in personalized medicine.[9]

Discussion

The successful incorporation of CDSS's applications in clinical practice can be a very complex undertaking that involves different kinds of work activities associated with financial expenditures and a depth of knowledge and experience required by clinicians and users in general. Previously in this paper, we mentioned findings of many studies in which researchers have provided statistical evidence and clearly identified areas of clinical practice deemed to be improved by the use and/or integration of CDSS's. Similarly, Kawamoto et al.,[10] publicized the results of seventy studies in which CDSS's have shown to significantly improve clinical practice in 68% of trials. Final findings of their studies revealed that, 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". Similarly, Berner[11] identified four main criteria that demonstrate the effectiveness of CDSS's in clinical settings as they make alerts and reminders, suggestions at the point of care, actionable recommendations and computerized processes available to healthcare providers. Moreover, Greenes[1] also acknowledged the usefulness of CDSS's in preventing medication errors, raising patient safety and quality, aiding in cost-effectiveness and managing chronic diseases by helping clinicians to ensure drug doses are appropriate, check for drug interactions, use reminders and suggestions, avoid duplicate tests and improve data collection. (p. 550-553). Finally, Osheroff et al.,[12] agreed that CDSS's can beneficial to healthcare organizations by providing the following critical benefits:

i. Reduced resource wasted due to redundant and inefficient activities to support clinicians' decision making.

ii. Reduced costs of care (better testing, cheaper and more efficient use of medications and therapies, less staff rework, greater care delivery coordination).

iii. Reduced costs associated with medical errors (legal liability and averted safety problems).

iv. Reduced liability insurance premiums based on improved safety.

v. Increased revenue (from pay for performance incentives).

vi. Increased market share (from more engaged and satisfied patients).

vii. Improved staff retention by providing a high quality professional knowledge management and decision support environment.

viii. Improved staff utilization (redeploy QA nurse from chart reviews to CDS implementation).

ix. Enhanced leverage to improve outcomes from investments and data in CIS.

x. Enhanced quality of healthcare professional education provided by the organization.

xi. Im Improved health services research capabilities and ability to attract grants.

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Conclusion

In conclusion, it was demonstrated in this paper that CDSS's are recognized and agreed upon by many writers and experts as a useful means for improvements in clinical practice. Remarkably, despite some limitations related to a low percentage of studies that prove the role of CDSS's in improving clinical practice, the review of findings has truly shown that CDSS's can help improve and widen clinical practice in ways to enhance quality, safety and efficiency of the healthcare system. In addition to their use in personalized medicine and genomics, future expectations are for designers to make sure

that required details are provided to clinicians in terms of interaction and usage of such systems in order to teach others effectively from previous successes and failures and that further trials are conducted to appraise the clinical significance and value of specific CDSS's applications.

Although we have mentioned in this paper that the implementation of new technologies such as CDSS's applications have the potential to improve clinical practice, it important to fathom that the use of technology itself does not always translate into improvement of the delivery of healthcare services and patient health outcomes. Subsequently, Mercola acknowledged current drawbacks of American healthcare system despite increasingly implementation of clinical information systems and wrote "Preventable medical mistakes are the third-leading cause of death in the US, right after heart disease and cancer. In all, preventable medical mistakes may account for one-sixth of all deaths that occur in the US annually". Moreover, Mercola highlighted inefficacity and inefficiency of our healthcare system and stated "According to the latest estimates, between 210,000 and 440,000 Americans die from preventable hospital errors each year". Finally, latest world's health systems ranking from World Health Organization (WHO) placed the United States in 37th position behind countries such as Colombia, Cyprus, Dominica, Oman, Costa Rica and Chile.

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Conflict of interest

The author declares no conflict of interest.

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