TOOLS AND APPLICATIONS TO IMPROVE THE QUALITY OF CARE AND PATIENT SAFETY

Ioana Gadalean

Oncological Institute "I. Chiricuta", Cluj- Napoca

Daniela Ionescu

University of Medicine and Pharmacy "Iuliu Hatieganu" Cluj-Napoca

ABSTRACT: Research shows that automation is able to improve the quality and safety of care delivered by health care facilities. Recent advances in automation have the potential to improve all aspects of health care delivery, from diagnosis and treatment to administration and billing.
Material and methods. This review presents a summary of electronic clinical decision support for clinicians. We searched Medline, CINAHL and the Cochrane Controlled Trials Register for relevant studies using combinations of the following search terms: decision support systems, clinical; decision making, computer-assisted; reminder systems; medical informatics; communication; physician's practice patterns; decision support; and expert system. We also systematically searched the reference lists of included studies and relevant reviews.
Results. Diagnostics have improved with the introduction of higher resolution functional magnetic resonance imaging (fMRI), positron emission tomography (PET), and computed tomography (CT) scans, not to mention advances in laboratory medicine technology for superior analysis of blood, urine, and cultures. Automation used for treatment spans the gamut—from new infusion devices such as smart IV pumps to surgical technologies such as endoscopic surgical tools, improved lasers, and even surgery assisting robots (e.g., da VinciTM).
Conclusion. There is growing recognition that CDS, when well-designed and implemented, holds great potential to improve health care quality and possibly even increase efficiency and reduce health care costs.
KEYWORDS: quality of care, patient safety, clinical decision support.

I. INTRODUCTION

Clinical decision support (CDS) systems provide clinicians, staff, patients, and other individuals with knowledge and person-specific information, intelligently filtered and presented at appropriate times, to enhance health and health care.
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, [M+03] and the US Institute of Medicine has estimated that up to 98 000 US residents die each year as the result of preventable medical errors. [KCD99] 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. [VNW01]
To address these deficiencies in care, healthcare organizations are increasingly turning to clinical decision support systems, which provide clinicians with patient-specific assessments or recommendations to aid clinical decision making. [H+98]
Such systems have been shown to improve prescribing practices, [BG03, W+01, W+99] reduce serious medication errors, [KSB03, B+99] enhance the delivery of preventive care services, [SDB96, B+00] and improve adherence to recommended care standards. [H+98, S+99] 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. [S+99, H+01, 0+95]

II. METHODS

This review presents a summary of electronic CDS for clinicians. We searched Medline, CINAHL, and the Cochrane Controlled Trials Register for relevant studies using combinations of the following search terms: decision support systems, clinical; decision making, computer-assisted; reminder systems; medical informatics; communication; physician's practice patterns; decision support; and expert system. We also systematically searched the reference lists of included studies and relevant reviews.
We defined a clinical decision support system as any electronic or non-electronic system designed to aid directly in clinical decision making, in which characteristics of individual patients are used to generate patient-specific assessments or

recommendations that are then presented to clinicians for consideration.

Our inclusion criteria were any randomised controlled trial evaluating the ability of a clinical decision support system to improve an important clinical practice in a real clinical setting; use of the system by clinicians (physicians, physician assistants, or nurse practitioners) directly involved in patient care; and assessment of improvements in clinical practice through patient outcomes or process measures.

This review focuses on CDS systems of a type known as knowledge-based CDS because they include compiled clinical knowledge.

III. RESULTS

III.1. Technological Underpinnings

Common features of CDS systems that are designed to provide patient-specific guidance include the knowledge base (e.g., compiled clinical information on diagnoses, drug interactions, and guidelines), a program for combining that knowledge with patient-specific information, and a communication mechanism - in other words, a way of entering patient data (or importing it from the EMR) into the CDS application and providing relevant information (e.g., lists of possible diagnoses, drug interaction alerts, or preventive care reminders) back to the clinician. CDS can be implemented using a variety of platforms (e.g., Internet-based, local personal computer, networked EMR, or a handheld device). Also, a variety of computing approaches can be used. These approaches may depend on whether the CDS is built into the local EMR, whether the knowledge is available from a central repository (possibly outside the local site and accessed and incorporated locally when needed), or whether the entire system is housed outside the local site and is accessed, but not incorporated into the local EMR. In principle, any type of CDS could utilize any of these underlying computational architectures, methods of access, or devices. The choices among these elements might depend more on the type of clinical systems already in place, vendor offerings, workflow, security, and fiscal constraints than on the type or purpose of the CDS. Many of the technology differences described in the previous section need not be apparent to the user. The following factors may be more relevant to the clinician user or those assisting with implementation: (1) the primary need or problem and the target area of care for which the CDS is being considered (e.g., improve overall efficiency, identify disease early, aid in accurate diagnosis or protocol-based treatment, or prevent dangerous adverse events affecting the patient); (2) to whom and how the information from the CDS will be delivered; and (3) how much control the user will have in accessing and responding to the information. A key decision is whether CDS can help solve the need or problem identified.

CDS can provide support to clinicians at various stages in the care process, from preventive care through diagnosis and treatment to monitoring and follow-up. CDS as implemented today can include, for example, order sets tailored for particular conditions or types of patients (ideally based on evidence-based guidelines and customized to reflect individual clinicians' preferences), access to guidelines and other external databases that can provide information relevant to particular patients, reminders for preventive care, and alerts about potentially dangerous situations that need to be addressed.

The most common use of CDS is for addressing clinical needs, such as ensuring accurate diagnoses, screening in a timely manner for preventable diseases, or averting adverse drug events. [G+05] However, CDS can also potentially lower costs, improve efficiency, and reduce patient inconvenience. In fact, CDS can sometimes address all three of these areas simultaneously—for example, by alerting clinicians to potentially duplicative testing. For more complex cognitive tasks, such as diagnostic decision making, the aim of CDS is to assist, rather than to replace, the clinician, [Mil90, MM90] where as for other tasks (such as presentation of a predefined order set) the CDS may relieve the clinician of the burden of reconstructing orders for each encounter. [C+06] The CDS may offer suggestions, but the clinician must filter the information, review the suggestions, and decide whether to take action or what action to take. Table 1 below provides examples of CDS that address a range of target areas. For more examples of how various types of CDS can be applied to addressing specific improvement objectives, see the work of Osheroff and his colleagues. [C+06]

Table 1: Examples of CDS interventions by target area of care Target Area of Care

	Example
Preventive care	Immunization, screening, disease management guidelines for secondary prevention
Diagnosis	Suggestions for possible diagnoses that match a patient's signs and symptoms
Planning or implementing treatment	Treatment guidelines for specific diagnoses, drug dosage recommendations, alerts for drug-drug interactions
Followup management	Corollary orders, reminders for drug adverse event monitoring
Hospital, provider efficiency	Care plans to minimize length of stay, order sets
Cost reductions and improved patient convenience	Duplicate testing alerts, drug formulary guidelines

III.2. Impact on Care Process and Patient Health Outcomes

In 2001, Trowbridge and Weingarten summarized the results of several systematic reviews or meta-analyses of CDS RCTs [J+94, TW01]. Since that paper, several new reviews and additional RCT studies have shown similar results. [EHK07, A+08, W+08] The meta-analyses of studies of alerts and reminders for decision support have been fairly consistent in showing that they can alter clinician decision making and actions, reduce medication errors, and promote preventive screening and use of evidence-based recommendations for medication prescriptions. The data on how those decisions affect patient outcomes are more limited, although a number of studies have shown positive effects. [EHK07, A+08, W+08] Overall, the results indicate the potential of CDS to improve the quality of care.

IV. OUR EXPERIENCE

IV.1. Patient-controlled analgesia

Patient-controlled analgesia is a modern analgesia technique in which the patient is able to administer him/herself the analgesic through special devices known as PCA pumps. The main ways of administering the PCA are intravenous and peridural.
PCA refers to the self administration of opioids IV, if need be, by the patient him/herself. This technique employs a pump controlled by a microprocessor; the pump delivers a preset dose of opioid when the patient pushes a button. The notion of PCA is not limited to a single class of analgesics, neither to a single way or means of administration.
The PCA had the following advantages: appropriate pain management, on the condition the patient was well informed on how to use the pump, the fact that the patient could control his/her own pain and decided when to administer the drug (according to certain safety limits) and was independent from the medical staff that would have to administered the analgesic on request.
The disadvantages of the PCA refer to its elevated costs, the need to instruct medical personnel involved on the functioning of such devices, and the need to educate the patients on the safe use of the pumps. Compared to the conventional methods, the PCA ensures better analgesia at comparable prices.
The effect is due to a relative lower average of hospitalization days and the time dedicated by the average personnel to administering analgesics [SRN97].
The degree of satisfaction is an indicator of the prognostic and of a patient's vision on the efficiency of his/her treatment. The comparison between the PCA and conventional methods led to different results, testifying to significant differences [WG94] or the lack of all difference. Reduced post-surgery anxiety and less significant post-surgery depression are correlated with an increased satisfaction. [CB96]. The following positive aspects have been identified: control over the treatment [Sch96], immediate administration of the treatment, absence of injections, absent need to turn to the assistance provided by average personnel [***94, FDV96]. The negative aspects refer to an insufficient analgesia and/or the presence of adverse effects, lack of trust in the "machine", and fear of over dosage or dependence [Keh94].

IV.2. Substance administration devices with a steady preservation of the plasmatic concentration - target controlled infusion (TCI)

Manipulating such devices is in general the prerogative of anesthetist doctors, but medical assistants must know that such devices exist and what are their functioning principles.

Such devices have an incorporated computer that stores the pharmacokinetic models of the substances it administers. These models are theoretically designed according to a patient's age, gender, and weight, and are intended to maintain a steady plasmatic concentration of the administered substance. For substances that can be administered through the TCI technique, the values of the plasmatic concentration ensure an appropriate intensity of the anesthesia or sufficient analgesia. Thus, the administration of substances through the TCI technique avoids the over or under dosage of the substance that might be caused by a too small or too large a bolus.

After going through all the stages of turning on the devices, one needs to introduce in the pump's computer the patient's data and the required plasmatic concentration, and the machine will calculate the speed at which it needs to inject the substance in order to preserve the set concentration.

The TCI principle (Target Controlled Infusion):

A pharmacokinetic algorithm calculates the doses/debit required in order to reach and preserve a drug's plasmatic concentration, reaching in the same time an optimum concentration according to the target level.

IV.3. Clinical decision support software in the monitoring of patients

Horizon trends is a software that saves crucial time (for ex: through the identification of early signs of sepsis), provides clear visual indicators of a patient's development, and presents a precocious alarm system – notifying, with as much as 20 minutes in advance, events that might take place (according to trend).

Data is collected continuously and displayed as graphs, tables, or histograms that allow one to observe a patient's development in time and can clearly indicate parameter deviation from normal values.

$$
\begin{aligned}
C_1(t) = &-\mathrm{Rate}\,\frac{k_{21}k_{31}}{V_1 s_1 s_2 s_3} \\
&+\left\{\mathrm{Rate}\left[\frac{k_{21}k_{31}+(k_{21}+k_{31})s_1+s_1^2}{V_1 s_1 (s_1-s_2)(s_1-s_3)}\right]+\frac{C_1' s_1^2+[C_1'k_{21}+C_1'k_{31}+C_2'k_{21}+C_3'k_{31}]s_1+[C_1'+C_2'+C_3']k_{21}k_{31}}{(s_1-s_2)(s_1-s_3)}\right\}e^{s_1(t-t_0)} \\
&+\left\{\mathrm{Rate}\left[\frac{k_{21}k_{31}+(k_{21}+k_{31})s_2+s_2^2}{V_1 s_2 (s_2-s_1)(s_2-s_3)}\right]+\frac{C_1' s_1^2+[C_1'k_{21}+C_1'k_{31}+C_2'k_{21}+C_3'k_{31}]s_1+[C_1'+C_2'+C_3']k_{21}k_{31}}{(s_2-s_1)(s_2-s_3)}\right\}e^{s_2(t-t_0)} \\
&+\left\{\mathrm{Rate}\left[\frac{k_{21}k_{31}+(k_{21}+k_{31})s_3+s_3^2}{V_1 s_3 (s_3-s_1)(s_3-s_2)}\right]+\frac{C_1' s_1^2+[C_1'k_{21}+C_1'k_{31}+C_2'k_{21}+C_3'k_{31}]s_1+(C_1'+C_2'+C_3']k_{21}k_{31}}{(s_3-s_1)(s_3-s_2)}\right\}e^{s_3(t-t_0)} \qquad (8)
\end{aligned}
$$

Fig. 1. TCA mathematics

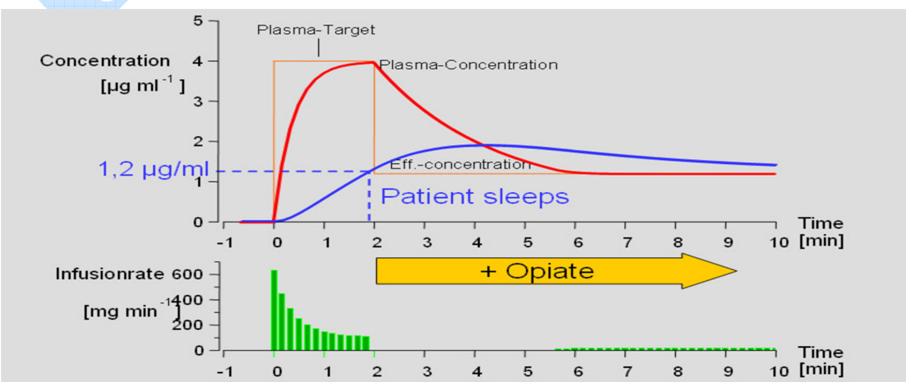

Fig. 2. TCI principle

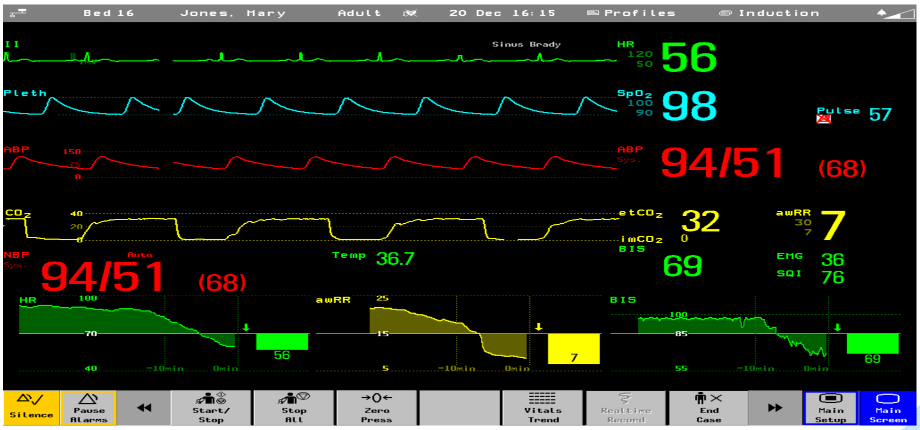

Fig. 3. Horizon Trends

IV.4. Protocol Watch

A. Software for the screening of patients with sepsis risk
The clinician decides what are the standard levels and the monitored parameters for patients' screening. When one or more parameters surpass the standard set values, the system signals and requests for the verification of other signs and symptoms that cannot be followed on the monitor. If the patient does not meet the criteria in the diagnosis of sepsis, the monitor remains in the screening stage and if the patient does meet these criteria, the monitor accesses the software allowing for the implementation of sepsis treatment guides.
B. Software allowing for the implementation of sepsis treatment guides
These softwares provide a list of treatment stages and the target parameters that the clinician must follow. Throughout the stage of treatment screening, the monitor constantly displays the trends of the most important vital parameters.

V.CONCLUSION

CDS automation has been recommended for many reasons:

• Reduced medication errors and adverse medical events
• Improved management of specific acute and chronic conditions
• Improved personalization of care for patients
• Best clinical practices consistent with medical evidence
• Cost-effective and appropriate prescription medication use
• Effective professional and consumer education about medication use
• Effective communication and collaboration across clinical/prescribing/dispensing/administering settings
• Efficient and convenient clinical practice and self-care
• Better reporting and follow-up of adverse events
• Compliance with accreditation and regulatory requirements
• Improved dissemination of expert knowledge from government and professional bodies to clinicians and patients

There is growing recognition that CDS, when well-designed and implemented, holds great potential to improve health care quality and possibly even increase efficiency and reduce health care costs. For the potential to be realized, CDS should not be viewed as a technology or as a substitute for the clinician, but as a complex intervention requiring careful consideration of its goals, how it is delivered, and who receives it.

ACKNOWLEDGMENTS

This study was conducted in the POSDRU/61577 program

REFERENCES

[A+08] **E. Ammenwerth, P. Schnell-Inderst, C. Machan et al.** – *The effect of electronic prescribing on medication errors and adverse drug events: a systematic review.* J Am Med Inform Assoc 2008 Sep; 15(5): 585-600.

[BG03] **J. W. Bennett, P. P. Glasziou** - *Computerised reminders and feedback in medication management: a systematic review of randomised controlled trials. Med J Aust* 2003; 178: 217-22.

[B+00] **E. A. Balas, S. Weingarten, C. T. Barb, D. Blumenthal, S. A. Boren, G. D. Brown** – *Improving preventive care by prompting physicians. Arch Intern Med* 2000; 160: 301-8.

[B+99] **D. W. Bates, J. M. Teich, J. Lee, D. Seger, G. J. Kuperman, N. Ma'Luf et al.** – *The impact of computerized physician order entry on medication error prevention. J Am Med Inform Assoc* 1999; 6: 313-21.

[CB96] **S. A. Coleman, J. Booker-Milburn –** *Audit of postoperative pain control: influence of a dedicated acute pain nurse. Anaesthesia* 1996; 51: 1093-6.

[C+06] **B. Chaudhry, J. Wang, S. Wu et al. –** *Systematic review: impact of health information technology on quality, efficiency, and costs of medical care.* Ann Intern Med 2006 May; 144(10): 742-52.

[EHK07] **S. Eslami, A. bu-Hanna, N. F. de Keizer –** *Evaluation of outpatient computerized physician medication order entry systems: a systematic review.* J Am Med Inform Assoc 2007 Jul; 14(4): 400-6.

[FDV96] **F. Fugère, P. Drolet, Y. Veillette –** *Bilan d'activité d'un service d'analgésie postopératoire dans un hôpital canadien. Ann Fr Anesth Réanim* 1996; 15: 313-9.

[G+05] **A. X. Garg, N. K. J. Adhikari, H. McDonald et al.** – *Effects of computerized clinical decision support systems on practitioner performance and patient outcomes.* JAMA 2005; 293(10):1223-38.

[H+01] **M. E. Hulscher, M. Wensing, T. van der Weijden, R. Grol –** *Interventions to implement prevention in primary care. Cochrane Database Syst Rev* 2001; 1: CD000362.

[H+98] **D. L. Hunt, R. B. Haynes, S. E. Hanna, K. Smith -** *Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. JAMA* 1998; 280: 1339-46.

[J+94] **M. E. Johnston, K. B. Langton, R. B. Haynes et al.** – *Effects of computer-based clinical decision support systems on clinician performance and patient outcome. A critical appraisal of research.* Ann Intern Med 1994 Jan; 120(2): 135-42.

[Keh94] **H. Kehlet -** *1993 John J. Bonica Lecture. Postoperative pain relief. A look from the other side. Reg Anesth* 1994; 19: 369-77

[KCD99] **L. T. Kohn, J. M. Corrigan, M. S. Donaldson** (eds.) – *To err is human: building a safer health system.* Washington, DC: National Academy Press, 1999.

[KSB03] **R. Kaushal, K. G. Shojania, D. W. Bates –** *Effects of computerized physician order entry and clinical decision support systems on medication safety: a systematic review. Arch Intern Med* 2003; 163: 1409-16.

[Mil90] **R. A. Miller –** *Why the standard view is standard: people, not machines, understand patients' problems.* J Med Philos 1990; 15(6): 581-91.

[MM90] **R. A. Miller, F. E. Masarie Jr. –** *The demise of the "Greek Oracle" model for medical diagnostic systems.* Methods Inf Med 1990 Jan; 29(1): 1-2.

[M+03] **E. A. McGlynn, S. M. Asch, J. Adams, J. Keesey, J. Hicks, A. DeCristofaro et al.** - *The quality of health care delivered to adults in the United States. N Engl J Med* 2003; 348: 2635-45.

[O+95] **A. D. Oxman, M. A. Thomson, D. A. Davis, R. B. Haynes –** *No magic bullets: a systematic review of 102 trials of interventions to improve professional practice. CMAJ* 1995; 153: 1423-31.

[Sch96] **P. Scherpereel -** *Faut-il développer en France des unités de traitement de la douleur postopératoire ? Ann Fr Anesth Réanim* 1996; 15: 255-6.

[SDB96] **S. Shea, W. DuMouchel, L. Bahamonde –** *A meta-analysis of 16 randomized controlled trials to evaluate computer-based clinical reminder systems for preventive care in the ambulatory setting. J Am Med Inform Assoc* 1996; 3: 399-409.

[SRN97] **B. R. Stacey, T. E. Rudy, D. Nelhaus –** *Management of patient-controlled analgesia: a comparison of primary surgeons and a dedicated pain service. Anesth Analg* 1997; 85: 130-4.

[S+99] **R. N. Shiffman, Y. Liaw, C. A. Brandt, G. J. Corb -** *Computer-based guideline implementation systems: a systematic review of functionality and effectiveness. J Am Med Inform Assoc* 1999; 6: 104-14.

[TW01] **R. Trowbridge, S. Weigarten –** *Clinical decision support systems. Making health care safer: a critical analysis of patient safety practices.* Rockville, MD: Agency for Healthcare Research and Quality; 2001. Evidence Report/Technology Assessment, No.43 AHRQ Publication No. 01-E058, p. 589-94.

[T+00] **M. A. Thomson O'Brien, A. D. Oxman, D. A. Davis, R. B. Haynes, N. Freemantle, E. L. Harvey –** *Audit and feedback versus alternative strategies: effects on professional practice and health care outcomes. Cochrane Database Syst Rev* 2000; 2: CD000260.

[VNW01] **C. Vincent, G. Neale, M. Woloshynowych -** *Adverse events in British hospitals: preliminary retrospective record review. BMJ* 2001; 322: 517-9.

[WG94] **S. E. Ward, D. Gordon -** *Application of the American pain society quality assurance standards. Pain* 1994; 56: 299-306.

[W+01] **R. T. Walton, E. Harvey, S. Dovey, N. Freemantle -** *Computerised advice on drug dosage to improve prescribing practice. Cochrane Database Syst Rev* 2001; 1: CD002894.

[W+08] **J. Wolfstadt, J. Gurwitz, T. Field et al.** – *The effect of computerized physician order entry with clinical decision support on the rates of adverse drug events: a systematic review.* J Gen Intern Med 2008 Apr; 23(4): 451-8.

[W+99] **R. Walton, S. Dovey, E. Harvey, N. Freemantle -** *Computer support for determining drug dose: systematic review and meta-analysis. BMJ* 1999; 318: 984-90.

[***00] ***** - The Royal College of surgeons of England and the college of anaesthetists.** *Commission on the provision of surgical services. Report of the working party on pain after surgery.* London: Royal College of Surgeons 1990.

[***94] *** - **NH & MRC.** *Management of severe pain. Report of the working party on management of severe pain.* Australian Government Publishing Service, Canberra 1988 31. Hughes JH. Comments on low cost acute pain services. *Pain* 1994; 59: 154-5.