A Medical Informatics Perspective on Clinical Decision Support Systems

Findings from the Yearbook 2013 Section on Decision Support

J. Bouaud[1, 2], J.-B. Lamy[3], Section Editors for the IMIA Yearbook Section on Decision Support
[1] AP-HP, Dept. of Clinical Research and Development, Paris, France
[2] INSERM UMRS 872 eq. 20, CRC, Paris, France
[3] Université Paris 13, Sorbonne Paris Cité, LIM&BIO, Bobigny, France

Summary

Objective: To summarize excellent research and to select best papers published in 2012 in the field of computer-based decision support in healthcare.

Methods: A bibliographic search focused on clinical decision support systems (CDSSs) and computer provider order entry was performed, followed by a double-blind literature review.

Results: The review process yielded six papers, illustrating various aspects of clinical decision support. The first paper is a systematic review of CDSS intervention trials in real settings, and considers different types of possible outcomes. It emphasizes the heterogeneity of studies and confirms that CDSSs can improve process measures but that evidence lacks for other types of outcomes, especially clinical or economic. Four other papers tackle the safety of drug prescribing and show that CDSSs can be efficient in reducing prescription errors. The sixth paper exemplifies the growing role of ontological resources which can be used for several applications including decision support.

Conclusions: CDSS research has to be continuously developed and assessed. The wide variety of systems and of interventions limits the understanding of factors of success of CDSS implementations. A standardization in the characterization of CDSSs and of intervention trial reporting will help to overcome this obstacle.

Keywords

Medical informatics, International Medical Informatics Association, yearbook, decision support systems

Yearb Med Inform 2013:128-31

Introduction

Medical decision support ultimately aims to deliver the best quality of care in accordance with current available knowledge. Computerized clinical decision support systems (CDSSs) are instruments to promote this goal. Though, the question of the effectiveness of CDSSs to enhance care quality arose long ago. Evidence of care improvement from past systematic reviews (e.g. [1, 2]) always yielded mixed results about the effects of CDSSs. With the growing deployment of IT in healthcare, the question of CDSS effectiveness is still topical, as reflected by this year's theme for the Yearbook "*evidence-based health informatics*". The goal of this section is to provide an overview of research trends pertaining to the development and implementation of CDSSs and to select "best" papers published in the past year that demonstrate excellent research or provide interesting insights related to computerized decision support.

About the Paper Selection

A comprehensive literature search was performed, using two bibliographic databases, Pubmed/Medline (from NCBI, National Center for Biotechnology Information) and Web of Science® (from Thomson Reuters). The search, targeted to decision support and computer provider order entry, yielded a total of 1124 references. These references were blindly reviewed by the two section editors, and classified into three categories: accepted, rejected, or pending. In the review process, papers were considered according to their contribution to one of these themes: originality of the application domain, description of a new method for medical decision support, evaluation of a CDSS, advice for the design of CDSSs, or review of the impact of CDSSs. Then, the two reviews were merged, yielding 57 references that were accepted by at least one reviewer or classified as "pending" by both reviewers. All these 57 references were reviewed again by the two section editors for reaching a consensual list of 15 candidate papers. Following the IMIA Yearbook process, these 15 papers where evaluated by editors and external reviewers (at least three reviewers per paper) and six papers where finally selected. Table 1 lists the selected papers. A content summary of the selected papers can be found in the appendix of this synopsis.

Conclusions and Outlook

The first selected paper perfectly fits the topic of this year's Yearbook, evidence-based health informatics: a systematic review by Bright et al. [3] on the effects of CDSSs in real settings considering different types of outcomes. It confirms that CDSSs can improve healthcare process measures and that evidence lacks to show a significant effect on other types of outcomes (e.g. clinical or economic). In the second paper, Pruszydlo et al. [4] describe a CDSS aiming to help

to switch drugs when a patient is admitted to hospital. This is an original application for clinical decision support, which could prevent many drug errors and reduce the clinicians' workload during admission. The third paper by Rattinger et al. [5] evaluates a CDSS that secures antibiotic prescription for acute respiratory infections. Their experiment on CDSS-targeted antibiotic drugs showed a nearly elimination of unwarranted prescriptions. Riaño et al. [6] in the fourth paper present an ontology for chronic disorders and problems. They show how this ontology could be exploited for several DS applications, such as personalizing intervention plans and merging several of them into a unified plan. Drug alerts are frequently overridden by physicians and thus have little impact on practices. Tamblyn et al. [7] in the fifth paper present more detailed alerts featuring patient-specific risk estimates, and compare them to traditional alerts in a randomized trial. Westbrook et al. [8] in the sixth paper pay attention to drug prescribing errors and to the effect of two different commercial electronic prescribing systems. They show that the CDSSs were efficient in reducing procedural errors, but not clinical errors, some of them being related to the system use.

More broadly, current research around CDSSs continues to better delimit where they are beneficial: on which type of outcome CDSSs have an effect [3], what are the barriers to their adoption (e.g. [9]), which interaction modalities are most efficient (e.g. [7, 10]). In the domain of knowledge management for decision support, the use of ontologies and of semantic web technologies is expanding. Ontological resources can be reused across systems and many existing tools are freely available for dealing with ontologies, including editors and reasoners. Ontology-based CDSSs are now been developed [11, 6]. Other works develop approaches to model medical decision-making, for instance to better handle flexibility in guideline-based planning [12] or to optimize decision by combining several methods [13]. Thanks to recent works in cognitive sciences, the process of the medical decision is better known. B. Djulbegovic et al. proposed a formal model of medical decision-making based on the dual processing theory that accounts for the human component of the physician decision-maker [14]. The place and role of the decision-maker when delivering decision support are of primary importance and should be better taken into account when implementing CDSSs according to Wu et al. [15], who proposed an interdisciplinary review of decision support outside the healthcare domain to inspire CDSS development. Based on a qualitative study, Ash et al. [16] issued recommended practices for the development and implementation of CDSSs.

Finally, drug prescribing remains a domain where computerized decision support yields positive results by reducing prescription errors, thus improving patient safety [4, 5, 7, 8]. As for the appraisal of the effectiveness of CDSSs in real settings, it is still reported that the conduct of interventions remains a difficult task [8]. Moreover, the wide variety of CDSSs and of interventions observed in published studies limits the conclusions of systematic reviews. A standardization in the characterization of the systems and of CDSS-based intervention trial reporting, as some authors [3, 17] call for, will certainly be necessary to better understand and evaluate the effects of CDSSs in the future.

Table 1 Best paper selection of articles for the IMIA Yearbook of Medical Informatics 2013 in the section 'Decision Support'. The articles are listed in alphabetical order of the first author's surname.

Section Decision Support
▪ Bright TJ, Wong A, Dhurjati R, Bristow E, Bastian L, Coeytaux RR, Samsa G, Hasselblad V, Williams JW, Musty MD, Wing L, Kendrick AS, Sanders GD, Lobach D. Effect of clinical decision-support systems: a systematic review. Ann Intern Med 2012 Jul 3;157(1):29-43.
▪ Pruszydlo MG, Walk-Fritz SU, Hoppe-Tichy T, Kaltschmidt J, Haefeli WE. Development and evaluation of a computerised clinical decision support system for switching drugs at the interface between primary and tertiary care. BMC Med Inform Decis Mak 2012 Nov 27;12:137.
▪ Rattinger GB, Mullins CD, Zuckerman IH, Onukwugha E, Walker LD, Gundlapalli A, Samore M, Delisle S. A sustainable strategy to prevent misuse of antibiotics for acute respiratory infections. PLoS One 2012;7(12):e51147.
▪ Riaño D, Real F, López-Vallverdú JA, Campana F, Ercolani S, Mecocci P, Annicchiarico R, Caltagirone C. An ontology-based personalization of health-care knowledge to support clinical decisions for chronically ill patients. J Biomed Inform 2012 Jun;45(3):429-46.
▪ Tamblyn R, Eguale T, Buckeridge DL, Huang A, Hanley J, Reidel K, Shi S, Winslade N. The effectiveness of a new generation of computerized drug alerts in reducing the risk of injury from drug side effects: a cluster randomized trial. J Am Med Inform Assoc 2012 Jul-Aug;19(4):635-43.
▪ Westbrook JI, Reckmann M, Li L, Runciman WB, Burke R, Lo C, Baysari MT, Braithwaite J, Day RO. Effects of two commercial electronic prescribing systems on prescribing error rates in hospital in-patients: a before and after study. PLoS Med 2012 Jan;9(1):e1001164.

Acknowledgement
We would like to thank Martina Hutter for her support and the reviewers for their participation in the selection process of the IMIA Yearbook.

References

1. Hunt DL, Haynes RB, Hanna SE, Smith K. Effects of computer-based clinical decision support systems on physician performance and patient outcomes. JAMA 1998;280(15):1339-46.
2. Haynes RB, Wilczynski NL; CCDSS Systematic Review Team. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: Methods of a decision-maker-researcher partnership systematic review. Implement Sci 2010;5(1):12.
3. Bright TJ, Wong A, Dhurjati R, Bristow E, Bastian L, Coeytaux RR, et al. Effect of clinical decision-support systems: A systematic review. Ann Intern Med 2012;157(1):29-43.
4. Pruszydlo MG, Walk-Fritz SU, Hoppe-Tichy T, Kaltschmidt J, Haefeli WE. Development and evaluation of a computerised clinical decision support system for switching drugs at the interface between primary and tertiary care. BMC Med Inform Decis Mak 2012;12:137.
5. Rattinger GB, Mullins CD, Zuckerman IH, Onukwugha E, Walker LD, Gundlapalli A, et al. Sustainable strategy to prevent misuse of antibiotics for acute respiratory infections. PLoS One 2012;7(12):e51147.
6. Riaño D, Real F, López-Vallverdu JA, Campana F, Ercolani S, Mecocci P, et al. An ontology-based

personalization of health-care knowledge to support clinical decisions for chronically ill patients. J Biomed Inform 2012;45(3):429-46.
7. Tamblyn R, Eguale T, Buckeridge DL, Huang A, Hanley J, Reidel K, et al. The effectiveness of a new generation of computerized drug alerts in reducing the risk of injury from drug side effects: a cluster randomized trial. J Am Med Inform Assoc 2012;19(4):635-43.
8. Westbrook JI, Reckmann M, Li L, Runciman WB, Burke R, Lo C, et al. Effects of two commercial electronic prescribing systems on prescribing error rates in hospital in-patients: A before and after study. PLos Med 2012;9(1):e1001164.
9. Kortteisto T, Komulainen J, Mäkelä M, Kunnamo I, Kaila M. Clinical decision support must be useful, functional is not enough: a qualitative study of computer-based clinical decision support in primary care. BMC Health Serv Res 2012;12:349.
10. Eslami S, Abu-Hanna A, Schultz MJ, de Jonge E, de Keizer NF. Evaluation of consulting and critiquing decision support systems: Effect on adherence to a lower tidal volume mechanical ventilation strategy. J Crit Care 2012;27(4):425.e1.
11. Rodríguez-González A, Emilio Labra-Gayo J, Colomo-Palacios R, Mayer MA, Miguel Gómez-Berbís J, García-Crespo A. SeDeLo: Using semantics and description logics to support aided clinical diagnosis. J Med Syst 2012;36(4):2471-81.
12. Grando MA, Glasspool D, Boxwala A. Argumentation logic for the flexible enactment of goal-based medical guidelines. J Biomed Inform 2012;45(5):938-49.
13. Grigull L, Lechner WM. Supporting diagnostic decisions using hybrid and complementary data mining applications: a pilot study in the pediatric emergency department. Pediatr Res 2012;71(6):725-31.
14. Djulbegovic B, Hozo I, Beckstead J, Tsalatsanis A, Pauker SG. Dual processing model of medical decision-making. BMC Med Inform Dec Mak 2012;12:94.
15. Wu HW, Davis PK, Bell DS. Advancing clinical decision support using lessons from outside of healthcare: an interdisciplinary systematic review. BMC Med Inform Decis Mak 2012;12:90.
16. Ash JS, Sittig DF, Guappone KP, Dykstra RH, Richardson J, Wright A, et al. Recommended practices for computerized clinical decision support and knowledge management in community settings: a qualitative study. BMC Med Inform Decis Mak 2012;12:6.
17. Augestad KM, Berntsen G, Lassen K, Bellika JG, Wootton R, Lindsetmo RO, et al. Standards for reporting randomized controlled trials in medical informatics: a systematic review of CONSORT adherence in RCTs on clinical decision support. J Am Med Inform Assoc 2012;19(1):13-21.

Correspondence to:
Dr Jacques Bouaud
INSERM 872, eq. 20
Centre de Recherche des Cordeliers
15, rue de l'école de médecine
75006 Paris, France
Tel: +33 (0) 1 44 27 92 10
E-mail: jacques.bouaud@sap.aphp.fr

Appendix: Content Summaries of Selected Best Papers for the IMIA Yearbook 2013, Section Decision Support[1]

Bright TJ, Wong A, Dhurjati R, Bristow E, Bastian L, Coeytaux RR, Samsa G, Hasselblad V, Williams JW, Musty MD, Wing L, Kendrick AS, Sanders GD, Lobach D

Effect of clinical decision-support systems: a systematic review

Ann Intern Med 2012;157(1):29-43

Assessing the effective impact of clinical decision support systems (CDSSs) is still a major concern. The paper summarizes the main results on this topic from a systematic review of the literature until January 2011 based on a more comprehensive report commissioned by the US Agency for Healthcare Research and Quality.

The review focused on randomized controlled trials of computer-based CDSSs that were actually implemented in real clinical settings, directed towards healthcare professionals to support their decision-making, and involving at least 50 participants. Authors considered several types of potential effects of CDSSs in their selection process: clinical outcomes, healthcare process, user workload and efficiency, economic outcomes, or provider use and implementation.

A total of 148 trials were selected, including commercially and locally developed CDSSs beyond experienced academic centers. Results confirmed improvements on healthcare process measures, which were assessed in 86% of the studies. There was limited evidence that CDSSs were effective in improving clinical outcomes. As for the other outcomes, evidence of positive impact remains unclear. Detailed results for more specific categories of outcome are provided in the tables of the paper. Authors mention the heterogeneity of the studies in their intervention, populations, settings, as well as their outcomes. They call for a better characterization of CDSS implementations and conclude that significant research is still needed to better understand keys to widespread adoption of CDSSs.

[1] The complete papers can be accessed in the Yearbook's full electronic version, provided that the article is freely accessible or that your institution has access to the respective journal.

Pruszydlo MG, Walk-Fritz SU, Hoppe-Tichy T, Kaltschmidt J and Haefeli WE

Development and evaluation of a computerised clinical decision support system for switching drugs at the interface between primary and tertiary care

BMC Med Inform Decision Mak 2012;12:137

In this article, the authors propose an original application for a clinical decision support system (CDSS). During the patient's admission to hospital, the drugs that the patient was taking outside the hospital are frequently not available in the hospital's pharmacy. Those drugs are therefore switched to other similar drugs, but with different form, dosage or active principle. This manual switching process involves about 1 drug out of 2. However the process is time-consuming and also leads to frequent errors, in about 1 substitution out of 5. The CDSS described by the authors is able to propose drugs for replacing the ones that are unavailable at the hospital.

The CDSS searches first for a pharmaceutic equivalent (same active principle, dose and form). If no equivalent is available, it searches for a pharmaceutic alternative (different dose, the dosage is then automatically modified, e.g. replacing 1 tablet at 100 mg by 2 at 50 mg). Finally, if no alternative is available, it searches for a therapeutic equivalent (different active principle but same therapeutic class, e.g. replace a statin by another statin and adapt the dosage as needed). The CDSS was evaluated and compared with the manual switches performed by clinical pharmacists at surgical wards of the University Hospital of Heidelberg. The system was able to switch automatically more than 90% of the drugs, without errors.

Rattinger GB, Mullins CD, Zuckerman IH, Onukwugha E, Walker LD, Gundlapalli A, Samore M, Delisle S

A sustainable strategy to prevent misuse of

antibiotics for acute respiratory infections

PLoS One 2012;7(12):e51147

This paper reports on the evaluation of a clinical decision support system (CDSS) used to prevent the misuse of antibiotics for acute respiratory infections. The CDSS was implemented as part of an existing order entry system in one Veterans Affairs (VA) site in 2003. According to guideline recommendations, the CDSS identified situations where some antibiotics had to be prescribed or could be safely withheld. The study is a retrospective pre-post intervention with another VA site, without the CDSS, as control site. The measured variables were the number of prescriptions of antibiotics when indicated, and when not indicated.

The pre-intervention period lasted 1 year and the post-intervention period 4 years. The intervention consisted of the CDSS triggering for 2 "targeted" drugs (azithromycin and gatifloxacin). 3831 patients were included from both intervention and control sites.

Results did not show any significant effect of the CDSS when the use of antibiotics was warranted, either between sites, between periods, or between targeted vs non-targeted antibiotics. However when the use of antibiotics was unwarranted, a significant decrease (from 22% to 3%, $p<0.0001$) of prescriptions of targeted drugs is observed on the intervention site between the pre- and post-intervention periods. Other comparisons are not significantly different. Since the CDSS intervention nearly extinguished unwarranted use of targeted antibiotics in this study, authors suggest this approach might be a path towards a better management of antibiotics, at least for acute respiratory infections.

Riaño D, Real F, López-Vallverdú JA, Campana F, Ercolani S, Mecocci P, Annicchiarico R, Caltagirone C

An ontology-based personalization of health-care knowledge to support clinical decisions for chronically ill patients

J Biomed Inform 2012;45(3):429-46

In this article, the authors present an ontology for the care of chronically ill patients, developed in the K4CARE project by an international team involving 5 European countries. The ontology includes 26 chronic problems (including diseases, but also disabilities and social issues), 293 signs and symptoms and 108 interventions (including drug treatments), and has been formalized with OWL-DL. It is linked with various medical terminologies, such as ICD 10 (International Classification of Diseases) and ATC (Anatomical Therapeutical Chemical classification of drugs).

The authors describe various applications of this ontology. First, for each chronic problem, a formal intervention plan is also provided, in a state-decision-action diagram. The ontology allows to personalize the intervention plan for a given patient, e.g. by pruning the branches of the plan that deal with comorbidities absent in that patient. It also allows to integrate several intervention plans into a unified plan, for patients suffering from several chronic problems.

Another application aims at helping physicians to enter patient conditions in medical records. The ontology includes relations between signs, diagnosis and interventions, which can be used to detect errors in medical records, or to suggest additional elements to the clinicians, e.g. suggest a diagnosis from signs.

Several evaluations were performed by the authors on the various applications, and concluded that the proposed tools were useful and provided high-quality decision support.

Tamblyn R, Eguale T, Buckeridge DL, Huang A, Hanley J, Reidel K, Shi S, Winslade N

The effectiveness of a new generation of computerized drug alerts in reducing the risk of injury from drug side effects: a cluster randomized trial

J Am Med Inform Assoc 2012;19:635-43

Drug alerts are already implemented in many Computer Order Provider Entry (CPOE) systems. However most of the alerts raised are overridden by physicians, because they consider that the drug's benefit is more important than the risk. In this article, the authors propose a more detailed alert with patient-specific risk estimates. The alert includes a risk thermometer indicating the patient's risk level, with and without the drug being prescribed.

The authors implemented this alert system for psychotropic drugs and the associated risk of fall injuries, using statistical models for computing risk estimates. They performed a cluster randomized trial comparing their alert system with a standard drug alert without risk estimates. The results of the trial showed a significant reduction of the risk of injury with the new alert system, especially for patients at high risk.

Authors conclude that individual risk estimates displayed graphically have a higher impact than traditional drug alerts, for reducing drug-induced injuries.

Westbrook JI, Reckmann M, Li L, Runciman WB, Burke R, Lo C, Baysari MT, Braithwaite J, Day RO

Effects of two commercial electronic prescribing systems on prescribing error rates in hospital in-patients: a before and after study

PLoS Med 2012;9(1):e1001164

This paper focuses on the effects of electronic prescribing (e-prescribing) as a mean to reduce prescription errors, but also as a potential source of new errors. The study adopted a before/after design following the actual introduction of two different commercial e-prescribing systems in three wards of two different hospitals. On one site, three wards not using the system were used as control. Prescribing error rates were computed for each period and ward, and errors were classified as procedural or clinical, with various subcategories, but also as serious or minor, and as system-related or not in the intervention wards.

The paper provides detailed results from the assessment of 3,291 medication charts for the whole study. Main result consists in a significant reduction of the rate of all prescribing errors in the intervention wards following the implementation of the e-prescribing system. However, only procedural errors were significantly reduced, while clinical errors were not. This trend was also observed for serious errors. As for system-related errors, findings show that they represented one third of all errors in the after-period in the intervention wards. These errors impacted mainly clinical errors, potentially annihilating the effect of the intervention.

Authors, apart from limitations of the study with respect to generalization, conclude that a close attention should be paid to system-related errors for they might limit the effectiveness of e-prescribing while being remediable by system design and user training.