Computer-Aided Decision Support Systems (CDSS)

SJ. Darmoni, MD, PhD & P. Massari, MD & N. Griffon, MD, PhD
Stéfan Jacques Darmoni = Professor of BioMedical Informatics, Rouen University Hospital & TIBS, LITIS, Normandy University

Philippe Massari = Medical Informatician, retired, 25 experience in medicine (cardiology & reanimation), SIBM

Nicolas Griffon = Medical Informatician, SIBM

Main fields of research
- CDSS (former field in the ’80s and ‘90s)
- Knowledge engineering
- Terminologies and ontologies, semantic web
- Information retrieval & automatic indexing
## SIBM in 2015

### Department of BioMedical Informatics

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CDSS: definitions

MeSH definitions... and its limits

- **Decision support systems, clinical** (n=9,089)
  - Computer-based information systems used to integrate clinical and patient information and provide support for decision-making in patient care.

- **Decision making, computer-assisted** (n=100,899)
  - Use of an interactive computer system designed to assist the physician or other health professional in choosing between certain relationships or variables for the purpose of making a diagnostic or therapeutic decision.

- Not located in the same tree (n=108,297) **AND ISRAEL** (n=1,016) (France 3,567)
  - As a terminologist, **Decision support systems, clinical IS A Decision making, computer-assisted**

To learn more:

Decision making, computer-assisted (MeSH Descriptor)

- information science
  - medical informatics
    - medical informatics applications
      - decision making, computer-assisted
- diagnosis, computer-assisted
  - image interpretation, Computer-Assisted
    - radiographic image interpretation, Computer-Assisted
  - therapy, Computer-Assisted
    - drug therapy, Computer-Assisted
  - radiotherapy, Computer-Assisted
    - radiotherapy planning, Computer-Assisted
  - radiotherapy, conformal
  - surgery, computer-assisted
Decision support systems, clinical (MeSH Descriptor)

Full tree

- MeSH top tree
  - Information Science Category
  - information science
    - medical informatics
    - medical informatics applications
    - information systems
      - decision support systems, clinical
Decision in medicine... and health

- The goal of medicine in 2015 is to obtain the best strategy, which leads to the maximum benefit for the patient (and the population), whereas the risks and the costs should be minimized.

- Two main steps in the medical decision:
  - Decision about diagnosis
  - Decision about therapy

- In the process of care, several (minor) types of decision may occur (e.g. procedure, imaging, lab tests).
How a physician (or HP) is taking a decision?
- Complex processus, which needs reasoning, based on facts and confronting to knowledge

Before CDSS, it is necessary to study this complex processus to perform an adequate decision in medicine (and health)
Basis of a decision

- **Facts**
  - All the facts that can be retrieved from patient interview, the examination, lab tests, imaging, procedures...

- **Clinical skills**

- **Knowledge**
  - Most up-to-date knowledge,
    - in the memory of the HP
    - In a (electronic) book or Web site
  - More and more knowledge are integrated into clinical guidelines
  - Computer-aided (assisted) access to guidelines or computerized guidelines (contextual knowledge)
  - Two Israeli teams in this area
    - Yuval Shahar (Ben Gurion University, Beer Sheva)
    - Mor Peleg (Haifa University)
Methods of reasoning

Several methods of reasoning exist:

- Deduction
- Abduction
- Induction
- Causal

These methods may be combined in a global process => Hypotheses & deducing, which is the most used process in medical diagnosis
Hypotheses & deducing reasoning
Formulation of hypotheses

Acute thoracic pain

Formulation of hypotheses

Coronary pain
Pulmonary embolism
Aortic dissection
Other etiologies

Three main etiologies are selected
Hypotheses & deducing reasoning

Evaluation of hypotheses

Search of sign in favour of this hypothesis

Coronary pain

Pulmonary embolism

Aortic dissection

For coronary pain
• history
• retrosternal pain
• irradiation
• EKG

For Aortic dissection
• Marfan, arterial hypertension
  • irradiation => back
• Abolition of pulse
• Aortic insufficiency

Evaluation of hypotheses
Hypotheses & deducing reasoning

Global schema

Number of hypotheses

- None
  - Search for other signs corresponding to other etiologies
  - Evaluation of hypotheses

- One
  - Final diagnosis
  - Evaluation of hypotheses

- Several
  - Search for other signs (lab tests, procedures, imaging)
  - Evaluation of hypotheses

Normandy University
All the phases of a medical decision could be computer-assisted

- Gathering data, using interactive actions
- Access to knowledge bases (information bases)
  - Drug databases, genetic databases
  - Terminologies and ontologies => teaching +++
  - Computerized guidelines, InfoButtons, documentary databases?
- Every step of the decision process, including reasoning +++
Computer-aided decision

- Decision process
- Objective: to allow the physician to take care of the patient with the CDSS to the best of the patient, minimizing the risk (first, do not harm)
- Several types of CDSS
  - Algorithm (computerized guidelines)
  - Expert systems
  - Probabilistic systems
  - Neural network (black box)
Computer-aided decision

- All the phases of a medical decision could be computer-assisted
  - Gathering data, using interactive actions
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Algorithm

- Simplest method but really easy to understand for a MD
- Nodes (questions or decisions) & arcs
- Tree or graph
- Decision tree (theory of decision)
  - Ponderation of each node
- Vidal Recos
  - 175 algorithms for GPs
  - Paper book: quite a success (n>50,000)
  - Electronic book integrated into Vidal suite (including a drug database)
Assessment of overweight patients

Source: wikipedia

1. Patient Encounter
   - Hx of ≥ 25 BMI?
     - No
     - BMI measured in past 2 years?

4. Measure weight, height, and waist circumference
   - Calculate BMI

5. BMI ≥ 25 OR waist circumference > 88 cm (F) > 102 cm (M)
   - Yes
   - Assess risk factors

7. BMI ≥ 30 OR BMI 25 to 29.9 OR waist circumference > 88 cm (F) ≥ 102 cm (M) AND ≥ 2 risk factors
   - Yes
   - Clinician and patient devise goals and treatment strategy for weight loss and risk factor control
   - Does patient want to lose weight?
     - No
     - Progress being made/goal achieved?
       - No
       - Assess reasons for failure to lose weight
         - Maintenance counseling
           - Dietary therapy
           - Behavior therapy
           - Physical activity
         - Periodic Weight Check
           - Brief reinforcement/educate on weight management

10. Yes
    - Progress being made/goal achieved?
      - No
      - Assess reasons for failure to lose weight
        - Maintenance counseling
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11. Yes
    - Progress being made/goal achieved?
      - No
      - Assess reasons for failure to lose weight
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          - Behavior therapy
          - Physical activity
          - Periodic Weight Check
            - Brief reinforcement/educate on weight management

* This algorithm applies only to the assessment for overweight and obesity and subsequent decisions based on that assessment. It does not include any initial overall assessment for cardiovascular risk factors or diseases that are indicated.
Ischemic stroke
Vidal Recos 2005

Maintenance of CDSS +++

½ life in medicine = 7 years

PhD in SIBM (A. Merabti)
Automatic detection of knowledge modification among two guidelines on the same subject
Bayes’ theorem

Conditional probabilities

P(A|B) difficult to compute

More easy to compute p(B|A)

Each hypothesis has a probability, which evolve according to the presence or absence of a sign (or a procedure)

Stop if a threshold is obtained

Population database necessary+++.

One of the most famous CDSS in the history
De Dombal et coll. Human and computer-aided diagnosis of abdominal pain: further report with emphasis on performance of clinicians. BMJ 1974
Leeds on ‘acute’ abdomen
As efficient as the senior surgeon
Much less efficient outside Leeds
Expert systems

- Main idea is to dissociate knowledge and computerization (inference engine)
- Mimicking the process of human expert
- From production rules, ES are able to process the reasoning

Production rules
- If A and B then C
- If thoracic pain and troponin then diagnosis = myocardial infarction

Introduction of a likelihood coefficient
- If A and B then C (x), with x ∈ [0, 1]
- If staph. Infection and hospital then staph. Methy resistant (0.8)
- If staph. Infection and non hospital then staph. Methy resistant (-0.4)

Order 0, 0+ (temperature > 38), 1 (f(x), generalization to one drug class)
Expert systems

- Interface
- Fact base
- Explanation module
- Knowledge base
- Inference engine
Expert systems

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- Mimicking the process of human expert
- From production rules, ES are able to process the reasoning
- Production rules
  - If A and B then C
  - If thoracic pain and troponin then diagnosis = myocardial infarction
  - If betablockers then… (explosion of the concept ‘betablockers’ to all the drugs of this therapeutic class)
- Mycin (most famous ES in medicine)
- Internist (all the knowledge of internal medicine)
Alerte fatigue +++

- Very important phenomena when HP use CDSS
- Too many alerts => stop using the CDSS
- Very well documented with drug databases (testing the drug interactions using CPOE)
  - Four levels of drug interactions
  - Only the two more serious activate an alert
    - Could be sometimes dangerous
CDSS evaluation

- Inspired by clinical trial
- Four phases
  - Phase I: validation in silico (in the lab); coherence of the knowledge
  - Phase II: evaluation in vitro (in the lab), including
    - GUI evaluation (ergonomy, +/- qualitative evaluation)
    - Feasability study: quantitative evaluation on a small sample
  - Phase III: formal evaluation
    - Randomized trial (a group with CDSS and a group without CDSS)
    - E.g. in France, current trial with/without DP in three medical specialties
  - Phase IV: post-marketing;
    - iterative evaluation over time (testing the maintenance of the CDSS)
    - evaluation outside the place of development (testing the portability)
CDSS evaluation: based on systematic reviews

**CDSS are a way to overall improve healthcare**

- ≈ 2/3 of published studies, use of CDSS led to an improve of healthcare
  - Prescription are in phase with clinical guidelines (66/100 studies – systematic review of Garg in 2005)
  - Reducing the relative risk of prescription errors (8/10 studies – systematic review of Ammenwerth in 2008)
  - Reducing the relative risk by more than half of potential drug side effects when using CPOE (14/25 studies – systematic review of Ammenwerth in 2008)
- in the other cases, no improvment or worse => e-vigilance (FDA)

**FIRST DO NOT HARM**

- Certification of CDSS +++ clinical information systems => CMIO (new job opportunity)
- Mean amplitude of improving are still relatively modest (systematic review of Shojania in 2010);

Significan clinical improvment :
  - 5 to 10% in ≈ 1/3 of the 28 studies ,
  - >10% in ≈ ¼ of these studies
Fuzzy limits: CDSS?

- Documentary Information Systems
  - PubMed alone +/-
  - CRBM: access to PubMed in Franch, automatic translation: yes
- InfoButton
  - Defined by JJ. Cimino (US)
  - Accessed to contextual knowledge
- CPOE
  - Yes, when testing drug interactions
Access to PubMed in your native language

Randomized Clinical Trial Efficient: 37.2% vs. 17.5% perfect queries (gold standard) p<0.0001

Same query for three different databases
URL: inforoute.chu-rouen.fr/ir
Bilingual search Fr En

Several accesses to PubMed
CDSS: not a big success overall

- Thousands of CDSS developed in the last 40 years
- Few were properly evaluated (randomized trial)
- Less in real use
- When in use in few institutions in the US
  - More CDSS are implemented, more the results are positive
  - Positive feedback
  - Integration of CDSS into health (hospital) information systems
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CDSS: main key factors of success

- Well adapted to work process
- Standard forms to knowledge engineering used by CDSS
- Integration of CDSS into health (hospital) information systems
  - Avoid double entry; avoiding double interface to manage
  - MD staying in his/her software
- Automatic triggering of CDSS, without interfering with the MDs => avoiding alert fatigue
- Providing the right information (knowledge) to the right person at the right time
CDSS: main key factors of success

- For computerized guidelines
  - Display an action and not an observation
    - action: reduce the prescription of drug X by Y mg because of creatinin clearance
    - observation: the creatinine clearance is diminished
  - Execute the proposed guidelines in your own EHR
    - Formalization of guidelines (RDF/XML)
    - UK NHS Quality Outcomes Framework for GPs
    - Clinical Decision Support Initiative, US AHRQ
    - In France, HAS (equivalent to US AHRQ) << Vidal (private company)
Clinical Decision Support Consortium

- Partners Healthcare (Boston)
- Department of Biomedical Informatics (Regenstrief Institute, Veterans Health Administration, Kaiser Permanente)
- Private companies (Siemens, GE Healthcare, NextGen)

Objectives
- State of the art
- Develop a model and methods to translate the knowledge included in guidelines to create efficient CDSS
- Build KBs at the US federal level to be reused
- Evaluate and disseminate
GuideLines Into DEcision Support

Yale University + Nemours Foundation

Objectives

- Develop computerized guidelines about chronic diseases and primary prevention
- Evaluate on GE Healthcare & EPIC Systems
CDSS: and now?

- National initiatives to promote CDSS
  - In Europe, besides UK and nordic countries, few countries are using CDSS

- Three main obstacles:
  - Resistance of end-users
    - Not enough integrated in the daily practice
    - Loss of time
  - Complexity and costs of CDSS KBS; huge difficulties to reuse it and to share it (maintenance +++)
    - Semantic interoperability

- Relative consensus to promote CDSS in OECD countries
  - Security, confidentiality, vigilance of CDSS
  - Certification of clinical information systems; rewarding good practice; pay for reporting; already existing in the US (FDA)
Future of CDSS?

- Integration of CDSS into health (hospital) information systems
  - Already a fact in four main institutions in the US
- Apps
  - Calculation of several parameters (BMI)
  - Internet of things
    - Integration of Internet of things into health (hospital) information systems => semantic interoperability