: What is the history of Clinical DSS?

by Daniel J. Power

Editor, DSSResources.COM

Clinical Decision Support Systems (CDSSs) are positively disrupting healthcare and the practice of medicine. Research about decision support, broadly defined, can benefit from greater knowledge sharing and from a greater understanding of prior research and innovation. CDSSs are not new innovations, they have been built and studied for almost 50 years. Also, CDSS share a common root with Business and Management Decision Support Systems (DSS), cf., Gorry and Scott-Morton (1971). For many years, the demand for a wide variety of decision support, especially related to CDSSs, has increased. This column explores the history of CDSSs.

Wyatt and Spiegelhalter (1991) define Clinical Decision Support Systems (CDSSs) as "active knowledge systems which use two or more items of patient data to generate case-specific advice". A more detailed definition from
Osheroff, Levick, Saldana, Velasco, Sittig, and Rogers (2012) is "Clinical decision support is a process for enhancing health-related decisions and actions with pertinent, organized, clinical knowledge, and patient information to improve health and healthcare delivery. Information recipients can include patients, clinicians, and others involved in patient care delivery; information delivered can include general clinical knowledge and guidance, intelligently processed patient data, or a mixture of both; and information delivery formats can be drawn from a rich palette of options that includes data and order entry facilitators, filtered data displays, reference information, alerts, and others."

Professor G. Anthony Gorry (1941-2018) was a DSS and a CDSS pioneer. Tony Gorry was the lead author of the seminal DSS article "A Framework for Information Systems" with Michael S. Scott-Morton (1971) that defined the concept of a decision support system. Gorry also authored and co-authored many important articles on CDSSs including Pauker, Gorry, Kassirer, and Schwartz (1976), Gorry (1978), Gorry, Pauker, and Schwartz (1978), Kassirer and Gorry (1978), and Gorry, Silverman, and Pauker (1978). Gorry graduated from and taught at MIT before joining Baylor College of Medicine as Vice President for Information Technology and Professor of Neuroscience (see Gorry CV). Gorry strongly influenced and helped define the fields of DSS and CDSS.

"Clinical decision support (CDS) provides clinicians, staff, patients, or other individuals with knowledge and person-specific information, intelligently filtered or presented at appropriate times, to enhance health and health care," e.g. Osheroff, Teich, Middleton, Steen, Wright, and Detmer (2007). Key functions of electronic clinical decision support systems are outlined in Perreault & Metzger (1999). Those functions include:
1) "Administrative: Supporting clinical coding and documentation, authorization of procedures, and referrals;
2) "Managing clinical complexity and details: Keeping patients on research and chemotherapy

protocols; tracking orders, referrals follow-up, and preventive care;
3) "Cost control: Monitoring medication orders; avoiding duplicate or unnecessary tests; and
4) "Decision support: Supporting clinical diagnosis and treatment plan processes; and promoting the use of best practices, condition-specific guidelines, and population-based management." (cf., http://www.openclinical.org/dss.html#wyatt1991)

Research about the use of artificial intelligence/decision support systems in medicine began in the early 1970's and produced a number of experimental systems. Early systems include AAPHelp (de Dombal), INTERNIST I (Miller, Pople and Myers, 1974), MYCIN (Shortliffe, 1976), ONCOCIN, and DXplain. DXplain is one of the oldest clinical decision support systems that is still used. This system developed at Massachusetts General Hospital in 1986 contains one of the largest databases of information which includes diseases, data points, and clinical findings among others. CDSSs are considered a major category related to using artificial intelligence in medicine.

Wright and Sittig (2008) identified four phases associated with the chronological history of clinical decision support including 1) standalone decision support systems, 2) decision support integrated into clinical systems, 3) standards for sharing clinical decision support content, and 4) service models for decision support. The advent of smartphones and voice interfaces is likely a fifth phase.

Bates et al. (2003) in the “Ten Commandments” for CDS identified the following success factors: 1) speed is everything, 2) anticipate user needs and deliver in real-time, 3) fit into the user’s workflow, 4) little things can make a big difference, 5) physician users resist stopping their workflow, 6) changing direction is easier than stopping (especially if viewed as valuable), 7) simple interventions work best, 8) ask for additional information from the user only when you really need it, 9) monitor impact, get feedback, and respond, and 10) actively manage and maintain the knowledge-based systems.

The goal of CDSS has been to "use historical clinical data and relationships processed by Artificial Intelligence (AI) techniques to aid physicians in their decision-making process" (Keltch, Lin, and Bayrak, 2010). Gray (2018) notes "To improve the quality of patient care ... there needed to be the development of evidence-based decision support systems that demonstrated better outcomes in terms of decision-making compared to traditional processes and showed value to users."

A variety of technologies have been used to build a wide variety of CDSS. For example, Greenes (2014) reviews probabilistic and data-driven classification, decision analysis, Bayesian belief networks, database prediction: data mining and machine learning, heuristic modeling, rule-based systems, models and calculations, algorithms, and multistep processes, interactive dialogues and structured data entry control, computer-based consultations, and computer-based clinical practice guidelines.

In a systematic review of prior findings, Jaspers, Smeulers, Vermeulen, and Peute (2011) concluded only a few studies found any benefits on patient outcomes and many of these were too small in sample size or too short in time to reveal clinically important effects. They did note there "is significant evidence that CDSS can positively impact healthcare providers' performance with drug ordering and preventive care reminder systems as most clear examples. These outcomes may be explained by the fact that these types of CDSS require a minimum of patient data that are largely available before the advice is (to be) generated: at the time clinicians make the decisions." So more research is needed, but much has happened and progress has been made since the 1970s.

Understanding CDSS history is important. The Global Clinical Decision Support Systems (CDSSs) market generated revenue of approximately $1.57 billion in 2018, cf., BIS Research Report (2019). The BIS report notes "there is an increasing demand for clinical decision-making tools which assist a clinician in making well-informed decisions at the point of care, thus preventing misdiagnosis or medical error". A Google Trends analysis also shows the increased interest in and adoption of CDSS. In 2004. the phrase "decision support system" was searched for 2-3 times more frequently than the phrase "clinical decision support system". By June 2009, search frequency crossed with both terms searched for at about the same frequency. By 2015, search frequency for clinical decision support systems was searched for more than twice as frequently. Clinical decision support systems is currently a more popular search term than decision support systems. This shift in search is likely due to the emphasis on analytics in the past five years in supporting business decision making. The country analysis shows the Chinese are searching for content related to decision support systems more frequently than CDSS. That pattern is reversed with a greater interest in CDSS in the United States, Canada, and Western Europe.

Decision support, analytics, and expert systems continue to evolve and expand in terms of application scope and capabilities. Clinical decision support vendors are incorporating AI and machine learning into their products (Siwicki, 2018). In many ways, Clinical Decision Support has surpassed other domains using decision support especially in terms of successful outcomes and results, research funding, and acceptance and adoption.

Timeline Clinical Decision Support Early Years (1959 through 1993)

This timeline is based upon prior materials that have been verified including https://www.clinfowiki.org/wiki/index.php/Timeline_of_the_Development_of_Clinical_Decision_Support

1959: Ledley and Lusted proposed in *Science* a mathematical model for diagnosis in their article

"Reasoning foundations of medical diagnosis." They asserted symbolic logic, probability, and value theory aid our understanding of how physicians reason. This article has been identified as the first scientific article in the field of Medical Informatics.

1961: Homer Warner, of the University of Utah, developed a mathematical model for diagnosing congenital heart disease. Their approach uses a contingency table with diagnoses as rows and symptoms as columns. The system predicts the diagnosis with the highest conditional probability given a set of symptoms.

1964: Morris Collen (1913-2014) of Kaiser Permanente developed a system for automated multiphasic diagnosis. Patients were given a stack of computer punch cards containing symptoms and questions, and they sorted them into Yes and No piles. A computer used these cards to develop a preliminary differential diagnosis. See Yardley, 2015).

1969: Howard Bleich developed a system to suggest therapy for acid-base disorders. It was the first decision support system to propose a management plan in addition to a diagnosis.

1972: F.T. de Dombal builds a probabilistic model to diagnose abdominal complaints. The computer predicted the correct surgical diagnosis based on initial findings 91.8% of the time. On average, senior clinician predicted the diagnosis correctly 79.6% of the time.

1972: The Health Evaluation through Logical Programming (HELP) system formed the basis of many research projects in clinical decision support, including the COMPAS ventilator management system by Dean Sittig and an antibiotic advisor by Scott Evans.

1975: Ted Shortliffe of Stanford developed MYCIN, an expert system for antibiotic dosing. MYCIN consisted of three modules: a consultation system which collects information, applies the rules in its knowledge base, and recommends therapy; an explainer system, which explains these recommendations; and a rule acquisition syhstem, which an expert uses to build rules for the knowledge base. In early evaluation, Mycin suggested acceptable therapy 75% of the time, but it got better as more rules were added.

1976: Present Illness Program (PIP) system was developed by Pauker and Gorry. It evaluated patients with edema.

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1976: McDonald published "Protocol-based computer reminders, the quality of care and the non-perfectability of man", which looks at the clinical decision support system in the Regenstrief Medical Record System. In an experimental trial, McDonald found that physicians responded to 51% of the alerts they received, but provided the corresponding care only 21% of the time when alerts were not provided.

1981: INTERNIST-I was developed by Randy Miller, Harry Pople, and Jack Meyers. INTERNiST, a diagnostic decision support system, was the first decision support system to span all of internal medicine. Users would enter the findings for a case into INTERNIST, and the system would develop a differential diagnosis, and ask questions to improve this diffential. The system contained 500 disease profiles, and 3,550 clinical manifestations.

1983: Perry Miller developed the ATTENDING system for anesthesia management. ATTENDING is the first medical critiquing system.

1987: Octo Barnett developed DXPlain, a diagnostic decision support system similar to INTERNIST. A web version of DXPlain is still available today.

1993: Brigham and Women's Hospital released Brigham Integrated Computing System (BICS), developed by Jonathan Teich.

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see http://www.openclinical.org/dss.html#wyatt1991

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Author: Daniel Power
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