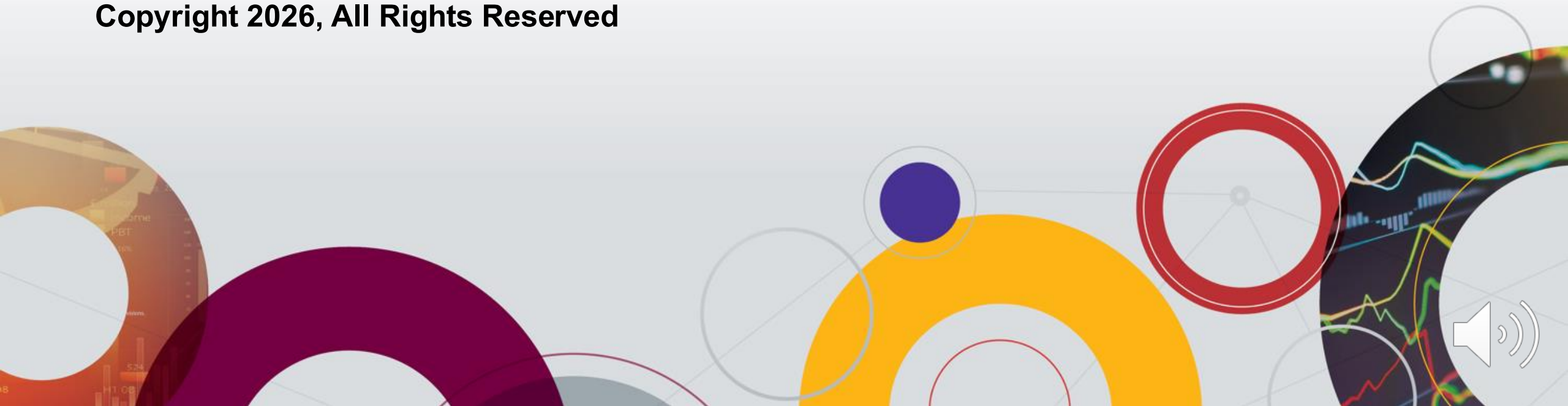


3.5a Clinical Decision Support

10x10 – Introduction to Biomedical Informatics & Artificial Intelligence
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From AI and expert systems to clinical decision support (CDS)

Early efforts to “quantify diagnosis” led to first era of AI and expert systems

- Most success with rule-based and scoring-and-heuristics systems

By late 1980s and early 1990s was apparent that

- Diagnostic process too complex for computer programs
- Systems took long time to use and did not provide information clinicians truly needed
- Manual construction of algorithms, rules, and knowledge bases not efficient or scalable

Decision support evolved in the 1990s with recognition of its value within EHR

- Rules-based approaches most useful in this context
- Evolution to more focused CDS

Clinical decision support (CDS)

“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” – AMIA Roadmap (Osheroﬀ, 2007)

Overviews (Osheroﬀ, 2012; Greenes, 2018; Sutton, 2021; Greenes, 2023)

May be used with computerized physician/provider order entry (CPOE), but

- CDS can be used outside setting of CPOE
- CPOE may not employ CDS

Epic jargon: best practice advisory (BPA)

CDS is applied in many tasks (Osheroff, 2012)

During data-entry tasks

- Smart documentation forms
- Order sets, care plans, and protocols
- Parameter guidance
- Critiques and warnings (immediate alerts)

During data-review tasks

- Relevant data summaries (single patient)
- Multi-patient monitors
- Predictive and retrospective analytics

During assessment and understanding tasks

- Filtered reference information and knowledge resources
- Expert workup and management advisors

Not triggered by user task

- Event-driven alerts (data-triggered) and reminders (time-triggered)

Toward modern CDS

Usually part of EHR

Reminders and alerts

- Preventive and other reminders
- Abnormal test result notification

Alert fatigue and CDS malfunction

Continued research

Standards and distributed tools

Computerized provider order entry (CPOE)

- Best practices
- Overrides and safety

Computer-based reminders are not a new idea

McDonald, 1976

- Computer-based reminders showed some reduction in error but humans are “non-perfectable”

Barnett, 1978

- Reminders to follow up Streptococcal pharyngitis to prevent acute rheumatic fever led to increased treatment
 - Returned to baseline when intervention ended

McDonald, 1984

- Paper printout of reminders to order routine preventive care resulted in increased utilization

Consistent findings from these results

- Behavior returned to baseline when reminders removed
- Effects were not educational



Other early successes

Test ordering reduced by displaying past results (Tierney, 1987) and costs (Tierney, 1990)

Antibiotic Assistant at LDS Hospital showed improved antibiotic selection, decreased costs, decreased ADEs, and decreased hospital length of stay (Evans, 1998)

Systematic review found numerous reports of benefits (Garg, 2005)

- Although better results for evaluations done by those who developed system

Issues concerning alerts

How to deliver to clinician?

- Pager? Phone call? Email?

Volume control, aka “alert fatigue”

- Want to communicate but not overload (not limited to medicine, e.g., Wald, 2010)

Medicolegal issues

- What to do about clinicians who do not respond to alerts or when alerts not appropriately generated

How to detect?

- Easier with coded or numeric data; harder for information in textual reports

How to standardize alerts across different systems

- Arden Syntax

Alert fatigue

Providers believe many alerts for abnormal test results unnecessary and unrelated to test (Hysong, 2011)

- Actual amount and time spent small but interruptive and noncritical nature most annoying (Elias, 2019)

Studies in literature show reduced alert fatigue by (Kane-Gill, 2017)

- Prioritizing alerts based on severity and clinical relevance
- Learning from previously overridden alerts to avoid future alerting
- Making more sophisticated alerts by incorporating biochemistry data and patient characteristics
- Focusing on atypical or rare prescribing events
- End-user opinion in use of alerts
- Customizing commercially available systems
- Appropriate selection of commercially available systems

Studies focused on medication safety have found value for (Hussain, 2019)

- Tiering by risk
- Providing shortcuts for common corrections
- Requiring a reason to override
- Tailoring CDS to match roles of pharmacists and prescribers

Alert fatigue – related problems and recommendations

Alarm fatigue

- Usually related to monitors in ICU (Drew, 2014)
- Solutions involve machine and human factors (Winters, 2018)

Inbox overload

- Burden of inbox notifications – at one site physicians received average of 76.9/day, taking up 66.8 minutes/day (Murphy, 2016)
- Algorithm-generated inbox messages – half of all inbox messages; higher level associated with physician burnout (Tai-Seale, 2019)

Subversion by commercial interests

- Pharmaceutical company paid EHR vendor Practice Fusion to promote prescribing of opioid drugs (Landi, 2020; Taitsman, 2020)

Reducing alert burden

From CDS leaders in four health systems (McGreevey, 2020)

Use of quality improvement methodology (Chapparo, 2020) – reduced interruptive alerts by almost half

Other methods

- “Snoozing” alerts that happen multiple times (Handler, 2022)
- “Clickbusters” to reduce number of clicks in CDS (McCoy, 2022)
- “Nudges” to frame desired behaviors more positively (Grouse, 2022)

1. Correct design inconsistencies and tailor alerts to meet the needs of the target population
2. Engage directly with impacted clinicians to redesign workflows (user-centered design/optimization)
3. Make all alerts actionable: assure the ability to jump directly to the intended action
4. Set standards for inclusion/exclusion logic across all care settings so that alerts do not impact unintended areas or users
5. Review trigger actions, align acknowledgment reasons, streamline verbiage
6. Standardize analyst capture of metadata when alerts are changed, to assure a reliable record of alert adjustments and the reasons for them, as well as the routine review of the alerts during change control

“Elements of style” for interruptive alerts (Pourian, 2025)

Name and identifier of patient in title

Orange color to indicate this is important but non-urgent alert

Descriptive, short name of alert

Non-italicized text is broadly applicable and forms skeleton of most alerts

Italicized text varies by alert; italicized text between asterisks varies by patient and clinician factors

If possible, include labs or studies relevant to alert

Default an action, if appropriate

Buttons should indicate reasons a clinician would opt out, including one free text

Buttons should describe effect they will have for which users

John Smith 12345678 01/01/1950 *Screening Colonoscopy*		
This patient is <i>due for a Colonoscopy</i> based on <i>*age*</i> , <i>*gender*</i> , and <i>*other risk factors*</i> . You are receiving this alert because <i>*you are a clinician*</i> and <i>*can order a colonoscopy, if one is indicated*</i> .		
Last Colonoscopy on file: <i>*Date and Time*</i>		
Ambulatory Colonoscopy	ORDER	Do NOT order
I am NOT <i>ordering a Colonoscopy</i> because:		
S/p colectomy (alert will never show again, for anyone)		
Patient refused (alert won't show for 1 year, for anyone)		
I'm not the patient's primary (alert won't show for 1 year, for me)		
Other (alert won't show for 3 months, for me) - Free Text		

CDS malfunction

Not uncommon; experienced by 93% of CMIOs (Wright, 2016)

Taxonomy of causes and effects (Wright, 2018)

Cause	How discovered	When discovered	Effect on Rule Firing
• Build error • Conceptualization error • New code, concept or term introduced, but rule not updated • Defect in EHR software • Environment migration • New value • Alert text mismatch • External service issue • Inadvertent enabling/disabling • Unaware of component reuse	• Reported by an end user • Review of firing data • Review of override reasons • Testing • Review of input data element usage • Demonstration of system • Found while investigating other error	• From its implementation in production • After deployment into production	• Rule fires in situations where it should not fire • Rule does not fire in situations where it should • Rule fires in the correct situations, but suggests the wrong action or displays the wrong text • Rule fires in the correct situations, but suggests the wrong action or displays the wrong text • Rule fires in the correct situation, but causes the EHR to operate slowly

Many causes of CDS malfunctions

Wright, 2016

- Alert for monitoring thyroid function in patients receiving amiodarone stopped working when internal identifier for amiodarone changed in another system
- Alert for lead screening for children stopped working when rule was inadvertently edited
- Software upgrade of EHR caused numerous spurious alerts to fire

Kassakian, 2017

- Inadvertent addition and removal of a medication code to electronic formulary list
- A seasonal alert not activated

Wright, 2019

- Strict hierarchies can cause unanticipated problems, e.g., carvedilol both alpha and beta blocker

Aaron, 2019

- Broken rules can be detected by override text

Wright, 2022

- Non-systematic routes for medication administration can lead to malfunction, e.g., beta blockers used for cardiovascular and eye conditions

Should there be regulation as a “device?”

Medical devices regulated in US Food & Drug Administration (FDA)

Classic view is that as long as there is “human in the loop,” regulation not required

More recent guidance more nuanced (2022) – CDS software functions excluded from definition of device if meet all of following four criteria

- Not intended to acquire, process, or analyze a medical image or a signal from an in vitro diagnostic device or a pattern or signal from a signal acquisition system
- Intended for purpose of displaying, analyzing, or printing medical information about a patient or other medical information (such as peer-reviewed clinical studies and clinical practice guidelines)
- Intended for purpose of supporting or providing recommendations to a healthcare professional about prevention, diagnosis, or treatment of a disease or condition
- Intended for the purpose of enabling health care professional to independently review basis for such recommendations that such software presents so that it is not the intent that such health care professional rely primarily on any of such recommendations to make a clinical diagnosis or treatment decision regarding an individual patient

Continued threads of research

Knowledge interventions still tend to extinguish with time, e.g., antibiotic stewardship (Gerber, 2014)

Half of closed malpractice claims could have been averted with appropriate CDS (Zuccotti, 2014)

Medication prescribing for certain groups, e.g., geriatric patients, still requires assistance to clinicians (Drago, 2020), which can be aided by CDS (Ota, 2020)

Systematic review shows small to moderate improvement in care processes, less so in patient outcomes (Kwan, 2020)

Threads of research (cont.)

Performance measurement of CDS (Dullabh, 2023)

Challenges and opportunities for patient-centered CDS (Sittig, 2024)

- Ensure patient-generated health data (PGHD) are documented, reviewed, and managed by appropriately trained clinicians
- Educate patients to use connected medical devices and handle technical issues
- Facilitate collection and incorporation of PGHD, patient-reported outcomes, patient preferences, and SDOH into existing EHRs
- Troubleshoot erroneous data received from devices
- Develop dashboards to display longitudinal patient-reported data
- Provide reimbursement to support new models of care
- Support patient engagement with remote devices.



What PC CDS Did You Design?

- User-centered Design
- Organizational Factors
- Software Performance
- Information Quality



What PC CDS Did You Build?

- Reach
- Adoption
- CDS Implementation Integrity
- Clinician Workflow Integration
- Patient Lifeflow Integration



What Were the Results?

- Usability
- User Satisfaction
- Alert Fatigue
- Clinical Guideline Adherence
- Policy and Safety Compliance
- Patient Engagement and Participation
- Shared Decision Making Processes
- Clinician Attitude and Beliefs
- Costs