Scaling, Measurement, and Dissemination Workgroup: PC CDS Performance Measurement Inventory User Guide

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Prepared by:
Prashila M. Dullabh, MD, ACHIP, FAMIA and Krysta Heaney-Huls, MPH
Priyanka J. Desai, PhD, MSPH
Frances Jiménez, MPH
Sofia Ryan, MSPH
Allison B. McCoy, PhD, ACHIP, FAMIA
Jerome A. Osheroff, MD, FACP, FACMI
CDSiC Scaling, Measurement, and Dissemination of CDS Workgroup

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PURPOSE

The Clinical Decision Support (CDS) Innovation Collaborative (CDSiC) Scaling, Measurement, and Dissemination of CDS Workgroup is charged with identifying measures of patient-centered clinical decision support (PC CDS) adoption, implementation, and use that can be used to scale safe and effective CDS tools beyond initial implementation sites. The Workgroup is comprised of 12 experts and stakeholders representing diverse perspectives related to CDS. This report is intended to be used broadly by those interested in measuring PC CDS performance.

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Contributors: CDSiC Scaling, Measurement, and Dissemination of CDS Workgroup

Members of the Scaling, Measurement, and Dissemination of CDS Workgroup who contributed to this report are listed below.

Name	Affiliation
Paul Dexter, MD	Regenstrief
Ben Hamlin, DrPH	National Committee for Quality Assurance (NCQA)
Christopher Harle, PhD	Indiana University
Polina Kukhareva, PhD, MPH	University of Utah
Tiffany Peterson	LupusChat
David M. Rubins, MD	Brigham & Women's Hospital
Dean F. Sittig, PhD	University of Texas
Christopher Tignanelli, MD, MS	University of Minnesota
Adam Wright, PhD	Vanderbilt University

Table of Contents

1. Introduction: The Importance of PC CDS Performance Measurement 1
   - 1.1 The Current Landscape of CDS Measurement 1

2. Performance Measurement Inventory: A Resource for Implementation and Research 2
   - 2.1 How Was the Inventory Developed? 2
   - 2.2 Who Should Use the Inventory and User Guide? 3
   - 2.3 How Can You Use the Inventory and User Guide? 3

3. Inventory Overview: PC CDS Performance Measures 5
   - 3.1 What PC CDS Did You Design? 6
     - 3.1.1 User-centered Design 6
     - 3.1.2 Organizational Factors 7
     - 3.1.3 Software Performance 7
     - 3.1.4 Information Quality 7
   - 3.2 What PC CDS Did You Use? 8
     - 3.2.1 Reach 8
     - 3.2.2 Adoption 9
     - 3.2.3 CDS Implementation Integrity 9
     - 3.2.4 Clinician Workflow Integration 10
     - 3.2.5 Patient Lifeflow Integration. 10
   - 3.3 What Were the Results? 11
     - 3.3.1 Usability 11
     - 3.3.2 User Satisfaction 12
     - 3.3.3 Alert Fatigue 12
     - 3.3.4 Clinical Guideline Adherence. 13
     - 3.3.5 Policy and Safety Compliance 13
     - 3.3.6 Clinician and Patient Knowledge 13
     - 3.3.7 Patient Engagement and Participation 14
     - 3.3.8 Shared Decision Making Processes 15
     - 3.3.9 Clinician Attitudes and Beliefs 15
     - 3.3.10 CDS Costs 16

4. Evaluating PC CDS Performance: Measurement Considerations and User Scenarios 16
   - 4.1 Measurement Considerations 16
   - 4.2 User Scenarios 17

4.2.1 Implementation User Scenarios 18
4.2.2 Research User Scenario 20

5. Measure Gaps and Limitations: Areas for Future PC CDS Measurement Research and Implementation 21
5.1 Measure Gaps and Recommendations 21
5.2 Inventory Limitations 24

Appendix A. Methods 25
Research Questions 25
Scoping Literature Review 25
Analysis and Synthesis 27
Technical Expert Panel 27
Measurement Inventory Development 28
User Scenario Development 28

References 29

List of Exhibits

Exhibit 1. PC CDS Measurement Inventory Organizing Domains and Measurement Categories 4

Exhibit 2. Number of Measures Across Implementation Phases 5

Exhibit 3. *What PC CDS Did You Design?* Measurement Categories 6

Exhibit 4. *What PC CDS Did You Use?* Measurement Categories Included in the Inventory 8

Exhibit 5. *What Were the Results?* Measurement Categories 11

Exhibit 6. User Scenario 1 Sample Measures 18

Exhibit 7. User Scenario 2 Sample Measures 19

Exhibit 8. User Scenario 3 Sample Measures 20

Exhibit 9. User Scenario 4 Sample Measures 20

Exhibit 10. PC CDS Performance Measurement Gaps and Recommendations 22

Exhibit A1. Key Search Terms for the Scoping Literature Review 26

Exhibit A2. Literature Search Inclusion and Exclusion Criteria 27

1. Introduction: The Importance of PC CDS Performance Measurement

Patient-centered clinical decision support (PC CDS) includes digital tools that have the potential to support patient-centered care by helping clinicians and patients make the best decisions given individuals' circumstances and preferences.[1]

The PC CDS lifecycle involves three overarching phases: knowledge generation, clinical decision support (CDS), and healthcare delivery.[2] Within each PC CDS lifecycle phase, it is important to consider the categories of measures that are appropriate to assess PC CDS performance. Evaluations of PC CDS performance should consider measures that assess the extent to which tools are safe, timely, effective, efficient, equitable, and patient-centered.[3]

What is Patient-Centered Clinical Decision Support (PC CDS)?

PC CDS is defined as CDS "tools that significantly incorporate patient-centered factors related to knowledge, data, delivery, and/or use."[1]

Factors include:

- Knowledge: Based on comparative effectiveness research or patient-centered outcomes research (PCOR) that incorporates outcomes that are meaningful to patients.
- Data: Data that are generated directly from patients such as patient-generated health data (PGHD), patient-reported outcomes (PROs), and/or nonclinical patient-centric data.
- Delivery: Directly engages patients and caregivers across a range of settings.
- Use: Supports direct patient and/or caregiver involvement in decision making and supports shared decision making.

1.1 The Current Landscape of CDS Measurement

CDS has been shown to improve healthcare processes such as recommended preventive care services and treatments. However, less evidence exists for clinical, cost, cost-effectiveness, workload, and efficiency outcomes.[4] Furthermore, variation exists in the tools and approaches used to measure and monitor PC CDS performance across the spectrum of design, development, implementation, and use.[5] This variation limits comparisons across CDS implementation studies, and as a result limits the evidence that leads to generalizable findings regarding CDS effectiveness.

Incremental progress continues in the standardized measurement of CDS effectiveness across CDS interventions, study design, and primary outcomes assessed, but much of the findings are limited in the statistical significance of positive clinical outcomes.[6] Additionally, much of the existing research on CDS measurement has focused on clinician-facing CDS, with an emphasis on alerts (e.g., firing and acceptance rates). Less research exists on understanding the patient-centered factors that impact intervention success, and there are few measures to assess PC CDS specifically.

Evaluating PC CDS design, development, implementation, and use are critical to helping implementers understand its impact. To advance the utility and scalability of PC CDS requires a better understanding of whether PC CDS satisfies the CDS Five Rights[7] (e.g., if it is delivering the right information to the

right people in the right ways) and how to improve the patient-centeredness of these tools. However, gaps exist in the measures and approaches used to assess PC CDS performance.[5]

A critical first step to improving the standardization and use of CDS measurement is establishing an undestanding of the measures currently available to assess PC CDS performance to help promote the consistent use of measures and measurement approaches, allowing for valid comparison across different types of CDS and different patient-centered interventions.

2. Performance Measurement Inventory: A Resource for Implementation and Research

The Performance Measurement Inventory focuses on measures for assessing the design, use, and process-related impacts of CDS. This user guide describes how the measures included in the Inventory are organized, provides user scenarios that serve as illustrative examples for how performance measures can be selected and used, and contains a brief discussion of measure gaps that PC CDS researchers and implementers should be aware of.

2.1 How Was the Inventory Developed?

The PC CDS Performance Measurement Inventory was developed through extensive collaboration between the Clinical Decision Support Innovation Collaborative (CDSiC) Scaling, Measurement, and Dissemination Workgroup leads, the CDSiC team, Workgroup members, and a Technical Expert Panel (TEP).

A scoping review was conducted by the CDSiC team to identify measures used to evaluate PC CDS performance. The scoping review focused on peer-reviewed literature on CDS measurement, PC CDS adoption, shared decision making processes and use of patient decision aids, and the impacts of CDS use on care team workflows and patient lifeflows.[a]

We searched PubMed in a multi-phased approach to identify peer-reviewed literature. The review began with a targeted search of systematic reviews of CDS studies to identify implementation and process outcome measures. The initial search of systematic reviews yielded 186 peer-reviewed articles from PubMed. We conducted additional searches of literature related to 1) CDS evaluation and implementation, and 2) CDS implementation process outcomes, which yielded 473 articles from PubMed. In total, these searches yielded 659 peer-reviewed articles.

In addition to the literature identified through the PubMed search, we reviewed articles recommended by Workgroup members and CDSiC team members, as well as additional peer-reviewed articles identified through snowball sampling of included literature. In total we screened 668 peer-reviewed articles and included 62 articles.

[a] Patient lifeflows are patient activities both within and external to a healthcare encounter that influence an individual's health.

Next, measures identified through the scoping review were categorized using an organizing structure developed with input from the Workgroup leads, Workgroup members, and the TEP. **Appendix A** provides additional details on methods used to develop the Inventory and organization structure.

This user guide also presents four user scenarios, developed through an iterative stakeholder-driven process, which illustrate how to use the Inventory to identify PC CDS performance measures.

2.2 Who Should Use the Inventory and User Guide?

This user guide is intended for a wide variety of potential users with different perspectives, goals, and roles related to PC CDS. Potential users range from community hospitals to academic medical centers, researchers, health system informatics leadership (e.g., Chief Informatics Officers), quality improvement teams, care team members, and patient partners, among others.

It serves to support users planning to select performance measures for evaluation, based on their intervention-related aims (e.g., evaluate the performance of an evidence-based PC CDS) and who they are (e.g., community hospital, clinician informatician, informatics researcher).

2.3 How Can You Use the Inventory and User Guide?

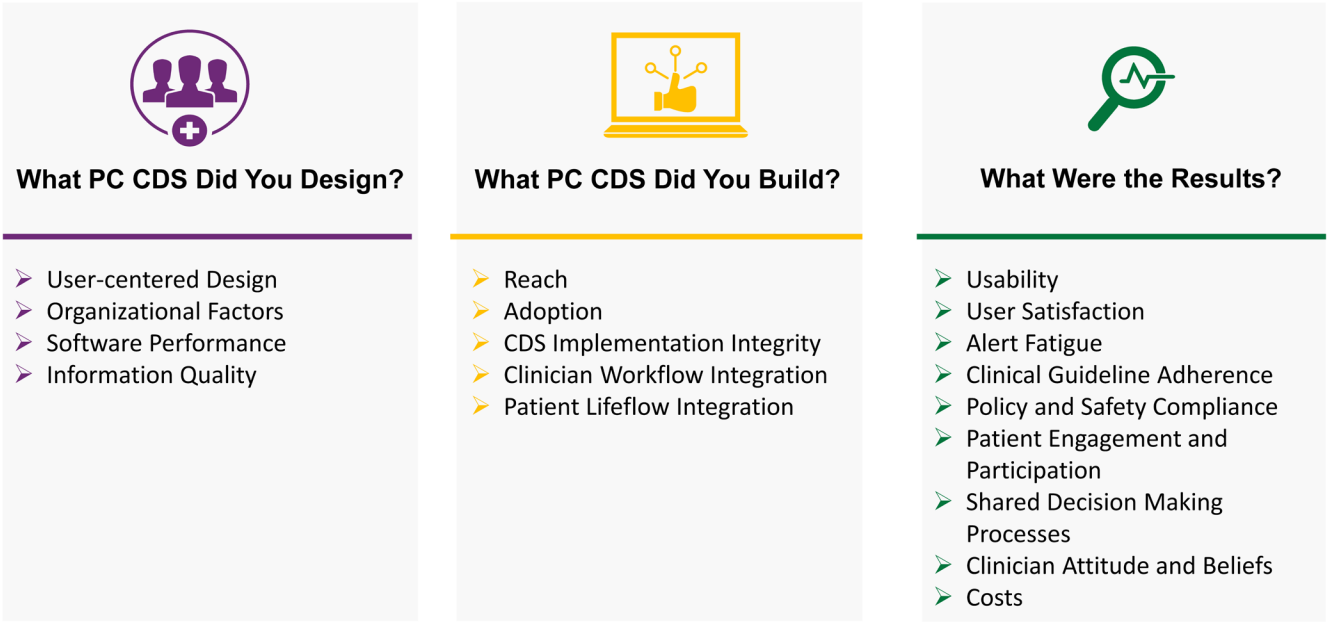
The overarching goal of the Inventory is to help PC CDS stakeholders interested in measuring PC CDS determine what to measure and how.

The PC CDS Performance Measurement Inventory aims to help users:

- Identify what measures are available to assess PC CDS performance.
- Identify the tools and measurement approaches reported in the literature to collect and analyze PC CDS performance data.

To facilitate the practical use of the Inventory by health systems, clinicians, informaticians, and others, measures in the Inventory are organized by three phases of PC CDS implementation: 1) *What PC CDS Did You Design?* 2) *What PC CDS Did You Use?* and 3) *What Were the Results?* Each implementation phase is stratified into measurement categories, and within the measurement categories are measure constructs that correspond to individual measures or metrics that can be used to assess PC CDS performance (**Exhibit 1**). For each unique measure included in the Inventory, we indicate the PC CDS intervention type that was studied (e.g., medication alerts, order sets, patient portals, decision aids).

Exhibit 1. PC CDS Measurement Inventory Organizing Domains and Measurement Categories



The following section of this user guide provides an overview of the measures contained in the Inventory organized by implementation phase. Within each implementation phase, we describe the measurement categories and present example measure constructs and available tools used to assess specific measures.

Next, we present general measurement considerations that users of this Guide and Inventory should take into account when planning for and designing a strategy for assessing and measuring PC CDS effectiveness. The user scenarios sub-section includes illustrative examples of how users addressing specific types of needs can leverage the Measurement Inventory.

This user guide concludes with a discussion of gaps in the measures identified to assess PC CDS performance and areas for future research to address these gaps.

Additional Measurement Resources from the CDSiC

- PC CDS outcomes measurement, including clinical outcomes, are discussed in the Patient-Focused Outcome Measures for Patient-Centered CDS resource.
- The PC CDS Implementation, Planning, and Reporting User Guide and Checklist is a tool for comprehensively describing how PC CDS is designed, developed, deployed, used, maintained, and evaluated along four key implementation domains: 1) planning and needs assessment, 2) design and development, 3) implementation and adoption, and 4) evaluation and impact.

3. Inventory Overview: PC CDS Performance Measures

While not an exhaustive list, the PC CDS Performance Measurement Inventory catalogues 163 unique measures derived from the literature to assess CDS performance across three phases of implementation: *What PC CDS Did You Design? What PC CDS Did You Use?* and *What Were the Results?* Of these, the greatest number of unique measures are related to process outcomes, with nearly half as many measures reported to evaluate use, and a handful of measures to assess implementation design. **Exhibit 2** presents the number of unique measures corresponding to each implementation phase.

Exhibit 2. Number of Measures Across Implementation Phases

Implementation Phase	Number of Unique Measures Identified
What PC CDS Did You Design?	15
What PC CDS Did You Use?	57
What Were the Results?	91

The most studied decision support tools were clinician-facing alerts, with an emphasis on medication management, including drug-drug interactions. There were far fewer studies of patient-facing PC CDS. In the three subsections that follow, we describe the performance measures reflected in the Inventory by implementation phase and measurement category. We also present example measures used to assess similar process outcomes and describe the approaches implementers report using. However, in the articles reviewed, researchers did not consistently report the methods or approaches used to assess a particular process outcome. Therefore, in this user guide we present the available information gleaned from the literature, and we note the consistent reporting of measurement methodologies as a gap.

PC CDS Performance Measurement Terminology & Key

Implementation Phase: Includes three phases corresponding to PC CDS development (i.e., design), deployment in a clinical setting (i.e., use), and assessment of healthcare delivery processes (i.e., results).

Measurement Categories: A grouping of measure constructs used to assess a similar theme.

Measurement Constructs: A grouping of individual measures that assess similar process outcomes.

Throughout Section 3, we use icons to delineate the descriptions of 1) the measurement categories and example measures included in the Inventory, and 2) the tools and approaches reported in the literature.

Delineates measurement categories

Delineates measurement tools and approaches for each measurement category, when available

The complete list of unique measures identified are provided in the **Measurement Inventory**.

3.1 What PC CDS Did You Design?

In the Measurement Inventory, the implementation phase *What PC CDS Did You Design?* is used to classify identified measures related to the development of PC CDS. We include measures that assess the process of ensuring the PC CDS addresses end users' needs, as well as ensuring the necessary data are available to trigger the decision support artifact. **Exhibit 3** presents the measurement categories used in the Inventory for the implementation phase, *What PC CDS Did You Design?*

Exhibit 3. *What PC CDS Did You Design?* Measurement Categories

Implementation Phase	***What PC CDS Did You Design?***
Measurement Category	• User-centered Design • Organizational Factors • Software Performance • Information Quality • Feasibility • Standards Conformance

We did not identify any measures that correspond to the measurement categories for implementation feasibility or standards conformance (i.e., measures that assess the extent to which the use of CDS standards[8] such as standard terminologies, information models, and standards for representing clinical knowledge in an executable format) support interoperability (i.e., portability) across organizations. As a result, the Inventory does not include measures for feasibility or standards conformance.

3.1.1 User-centered Design

User-centered design relates to the iterative health information technology (IT) software development process focused on understanding the target users, tasks, and context for use[9] and the application of user-centered design principles (e.g., heuristics). The Inventory includes two measure constructs that encapsulate the process outcomes that implementers report using to assess user-centered design: user interface design and user interface issues.

Measuring User Interface Design. Approaches to measuring features of the user interface focus on assessing users' perceptions of ease of use, findability of information, use of content familiar to the end user (e.g., concepts, icons), and user control to perform actions such as undoing an action. Usability is measured using tools such as the Health Information Technology Usability Evaluation Scale,[10] the Computer System Usability Questionnaire (CSUQ),[11] and the Nielsen heuristic principles.[12]

Measuring User Interface Issues. The identification of the user interface issues can help implementers to identify design features that enable or impede use.[13] Addressing these issues through design improvements can reduce the number of errors the user makes and promote safe use.[13] Approaches researchers have reported for assessing these user interface issues include think-aloud simulations to assess clinicians' competency to complete the desired clinical tasks without assistance and categorize the potential clinical severity of a use error.

3.1.2 Organizational Factors

Organizational factors describe the characteristics of the implementation site beyond the clinical setting alone. The Inventory includes two measure constructs used to assess the organizational factors that impede or accelerate clinician use of CDS: leadership support and resource availability.[14]

Measuring Organizational Factors. Researchers employed qualitive assessments to measure the degree of support from senior leadership or a clinical champion as well as the human resources and capital (i.e., IT hardware) available to implement CDS.[15]

3.1.3 Software Performance

Software performance measures assess the data elements used as decision logic data inputs, verify the logic's accuracy and its efficacy,[16] and assess decision support response times. The measures included in the Inventory related to software performance include data retrieval accuracy,[17] the availability of patient-specific data elements (e.g., clinician-entered data, registration data, laboratory data, pharmacy system data) needed as an input for the decision support logic,[15] and the accuracy of the decision support algorithm.

3.1.4 Information Quality

In the Measurement Inventory, we use information quality to describe the clinical validity of the decision support logic.[18] Researchers commonly use measures of alert sensitivity and specificity to assess clinical accuracy. Researchers also reported measuring alert currency and the accuracy of the studied decision support algorithm.

Measuring Alert Sensitivity and Specificity. Researchers reported calculating both 1) the degree to which an alert correctly identifies or detects patients, based on the decision support logic, to assess the sensitivity of the alert (i.e., the true positive rate, or the rate the alert fired for the appropriate patients) and 2) the specificity of the alert (i.e., the true negative rate, or the rate the alert inappropriately fires for wrong patients) using electronic health record (EHR) data. Relatedly, implementers reported using EHR data to determine the positive predictive value and absolute number of false positives.

Measuring Algorithm Accuracy. The literature we reviewed compared the accuracy of a machine learning risk prediction CDS against clinician risk ratings.[18]

3.2 What PC CDS Did You Use?

In the Measurement Inventory, the implementation phase *What PC CDS Did You Use?* is used to categorize process outcomes resulting from PC CDS use in a production environment. **Exhibit 4** depicts the performance measure categories we use to organize the use-related process outcomes described in the literature.

Exhibit 4. *What PC CDS Did You Use?* Measurement Categories Included in the Inventory

Implementation Phase	***What PC CDS Did You Use?***
Measurement Category	• Reach • Adoption • CDS Implementation Integrity • Clinical Workflow Analysis • Patient Lifeflow Integration

3.2.1 Reach

Reach focuses on the absolute numbers, proportions, and representatives of the patients, caregivers, and the care team members who used a CDS tool and who were identified by the CDS for a clinical task (e.g., patient meets clinical criteria for risk-appropriate screening, patient receives request to complete a health assessment).[19] The measures researchers report using to assess reach focused on quantifying the number of active users by tool and user type.[15]

Measuring CDS Users. Researchers report reviewing EHR data and patient portal registration and log data[20] to calculate the number of active users for a given CDS.

3.2.2 Adoption

In the Inventory, adoption measures assess how often a CDS tool had the potential to inform decision making. The included measure constructs that implementers reported using to monitor adoption focused on measures of alert acceptance (e.g., number of alerts acknowledged[21]), alert adherence (e.g., ratio of alerts to orders[21]), CDS uptake, and clinician perspectives on the accessibility of an order set.

Measuring Alert Acceptance. Researchers reported primarily using EHR data to measure acceptance and adherence to alerts.

Measuring Uptake. Measures to assess uptake of a CDS focused on the number, proportion, or duration of use generated by reviewing EHR data, data warehouse extracts, and patient portal usage logs.

3.2.3 CDS Implementation Integrity

The Inventory uses CDS implementation integrity to classify measures that assess the extent to which CDS works as intended.[22] Implementers report using a range of measures to assess implementation integrity. Given the rich literature on efforts to enhance CDS design and reduce alert fatigue, most of the CDS implementation integrity measure constructs focused on assessing whether alerts result in the desired outcome, with fewer measures used to assess if patient-facing and shared decision making CDS work as intended. Implementation integrity measures concepts and example measures corresponding specifically to alerts included alert appropriateness (e.g., was the right information provided to the right person[23]), alert compliance (e.g., alert override rate,[21] appropriateness of the alert override[24]), and alert malfunctions. Measures used specifically to assess the integrity of patient-facing CDS and shared decision making CDS included an implementation grade (i.e., the percentage of participants that actually used intervention as intended[25]), a decision aid fidelity score,[26] and compliance with a decision aid.

Measuring Implementation Integrity of CDS Alerts. Researchers reported primarily using EHR data to measure alert data integrity, with a few measures requiring chart review. To assess the number of alert malfunctions, researchers reported using visual anomaly detection, an approach that identifies ‘anomalies’ based on whether the alert firing appeared to deviate from historical patterns or exhibited behavior that appeared inconsistent with knowledge of the targeted activity.[27]

Measuring Implementation Integrity of Patient-facing and Shared Decision Making CDS. Researchers developed study-specific tools, thresholds, and scales to evaluate clinicians' decision making compared to decision aid guidance.[26]

3.2.4 Clinician Workflow Integration

Generally, workflow is defined as "the set of tasks—grouped chronologically into processes—and the set of people or resources needed for those tasks that are necessary to accomplish a given goal."[28] In the Inventory, clinician workflow integration is used to describe the intersection of the decision support with the tasks clinicians perform and assess changes to workflow processes. The Inventory includes the following measure constructs: efficiency—including temporal changes to clinician workflows, alert frequency,[15,21,29] and cognitive workload. Example efficiency measures include frequency of task switching and interruptions or workflow fragmentation,[30] task complete rates and use of workarounds,[31] time spent information seeking,[32] and impact on workflows such as changes in consultation time.[46] Measures of cognitive workload assess users' perceptions of mental demand, physical demand, temporal demand, effort, performance, and frustration level.[17]

Measuring Efficiency. Implementers used EHR data and a range of approaches to assess efficiency, including workflow modeling, time-motion studies, log analysis, video analysis, observation, screen capture software, and qualitative assessment.

Measuring Alert Frequency. Measures of alert frequency included in the Inventory include firing rates stratified by different intervals or clinical process (e.g., alerts per patient encounter, alerts per orders) utilizing data from the EHR.

Measuring Cognitive Workload. Implementers reported using the National Aeronautics and Space Administration (NASA) Task Load Index[33] (NASA-TLX) to assess cognitive workload.

3.2.5 Patient Lifeflow Integration.

In the Inventory, we consider the patient lifeflow to be how the patient interacts with the PC CDS both within and external to a healthcare encounter, which influence an individual's health. These activities include: 1) engaging in daily activities, 2) generating health data, 3) gathering health knowledge, 4) making health decisions, 5) taking self-care actions, 6) having the healthcare encounter, and 7) communicating with the patient's care team.[34,35] There were few measures to assess the impact of CDS use on patients' lifeflows. The measures identified included patient workload and time to receipt of appropriate care upon delivery after an order is placed.[36]

Measuring Time to Receipt of Appropriate Care. Implementers used chart reviews to ascertain the duration between ordering and receipt of appropriate care.

3.3 What Were the Results?

In the Inventory, the implementation phase *What Were the Results?* refers to measures that assess process-related outcomes. We include 11 measure categories used to assess performance-related process outcomes (see **Exhibit 5**). Implementers and evaluators can reference the Patient-Focused Outcome Measures for Patient-Centered CDS resource to identify clinical outcomes.

Exhibit 5. *What Were the Results?* Measurement Categories

Implementation Phase	***What Were the Results?***
Measurement Category	• Usability • User Satisfaction • Alert Fatigue • Clinical Guideline Adherence • Policy and Safety Compliance • Clinician and Patient Knowledge • Patient Engagement and Participation • Shared Decision Making Processes • Clinician Attitudes and Beliefs • CDS Costs

3.3.1 Usability

Usability is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use."[37] We identified usability measure constructs related to effectiveness, efficiency, and effort expectancy. For the Inventory, we consider user satisfaction measures separately. Measures to assess CDS tool effectiveness examined the rate of errors. Measures of efficiency examined time spent performing clinical tasks.[38] Example effort expectancy measures assess perceived ease of use.[14]

Measuring Effectiveness. Researchers used a variety of different tools to assess effectiveness, including qualitative interviews, the System Usability Scale (SUS),[39]CSUQ, and the Post Study System Usability Questionnaire.[40]

Measuring Efficiency. Implementers used scenario-based simulations to assess efficiency.

Measuring Effort Expectancy. Implementers used a combination of qualitative approaches, such as the think-aloud method and use case scenarios, and a quantitative data collection tool, the Technology Acceptance Model (TAM) Questionnaire,[41] to assess effort expectancy.

3.3.2 User Satisfaction

Satisfaction is a broad category of measurement that assesses users' perceptions of the features of the CDS and factors influencing implementation. The user satisfaction measure constructs identified by this review include acceptability, willingness to recommend the CDS, satisfaction with the user interface, satisfaction with the data quality, clinician satisfaction, patient satisfaction, trust, and the quality of the communication with the care team. Acceptability measures assess sustained clinician use of a CDS tool,[42] whereas willingness to recommend the CDS assesses overall satisfaction.[43] To understand the patient perspective, researchers used measures of patients' experience of care,[44] patients' trust with a clinician,[43] and the patient's satisfaction with the clinical encounter.[26,44,45,46]

Measuring Acceptability. Reported approaches to measuring acceptability focused on qualitatively describing users' perceptions, whether positive or negative, of the potential clinical impact[44] of a tool and the perceived threat to a clinicians' personal autonomy.[47]

Measuring Clinician and Patient Satisfaction. Approaches to assessing user satisfaction with CDS utilized validated measures such as the Net Promoter Score[43] to determine mean satisfaction. They also used a mix of validated and intervention-specific satisfaction questionnaires, such as the Global Satisfaction Scale,[44] American Board of Internal Medicine's Patient Satisfaction Questionnaire,[48] and the Consultation Satisfaction Questionnaire.[44]

3.3.3 Alert Fatigue

Alert fatigue is an oft-cited barrier to CDS implementation,[49] and alert fatigue is also a widely accepted explanation for high override rates.[50] While estimates differ, researchers have reported that half of all alerts are overridden.[51,52] Efforts identified to assess alert fatigue and understand its impact focus on measuring the perceived lack of alert relevancy and integration into the clinical workflow. Measure constructs to assess alert fatigue were alert appropriateness,[47] cognitive overload,[50] think time,[53] and desensitization.[50]

Measuring Alert Fatigue. Implementers used a mix of EHR data and chart review to calculate alert appropriateness, pre-post assessments of clinicians' perceptions of alert fatigue, as well as apply the Subjective Workload Assessment Technique[54] and the NASA-TLX.

3.3.4 Clinical Guideline Adherence.

A primary use of CDS is to improve healthcare processes and outcomes. Adherence to guidelines denotes the degree of compliance between clinicians' decision or action and the recommendation of clinical guidelines.[55] Several measures focus on the efficacy of the CDS to support adherence to evidence-based clinical guidelines and care recommendations. Examples of CDS intervention efficacy focus on process outcomes that assess changes in ordering and prescribing practices over time;[15] number of prescriptions with the recommended drug dose, frequency, route, timing, and duration;[56] percentage of test/treatments/exams completed; and number of procedures changed or canceled due to medication mismanagement.[57]

Measuring Guideline Adherence. The literature described using EHR data to measure adherence, with limited use of chart review.

3.3.5 Policy and Safety Compliance

Policy and safety compliance refers to organizational practices intended to satisfy regulatory requirements and reduce unintended consequences. Measure constructs of policy and safety compliance center on healthcare process outcomes. For example, the number of adverse drug events (ADEs),[4] medication prescribing error rates,[58] and duplicate orders.[15]

Measuring Policy and Safety Compliance. Implementers used EHR data and chart review to ascertain the number and proportion of ADEs and other safety-related errors.

3.3.6 Clinician and Patient Knowledge

Knowledge refers to an individual's understanding of information. Knowledge measure constructs include decisional quality, clinician knowledge and expertise, and patient knowledge. Changes in patient knowledge was among the most studied outcomes of patient decision aids.[59,60,61,62,63,64] Decision quality included patient self-reported changes in knowledge and was condition-specific. Measures of clinician knowledge and expertise assess clinicians' familiarity with using a CDS tool[47] and their confidence in the decision making process.[65] Patient knowledge assessments measured patients' knowledge about their medical condition and use of a medical device or tool,[26] as well as the quality of the decision the patient made. Assessments of patient knowledge also examined the extent to which a patient understands their different treatment options and accurately identified their risk category.[26]

Measuring Decisional Quality. Decision quality was assessed by determining the percentage of patients who accurately answered questions about their condition and received their preferred treatment.[66]

Measuring Clinician Knowledge and Expertise. Researchers reported using a mix of qualitative surveys as well as reviewing EHR documentation to evaluate the efficacy of the decisions made.

Measuring Patient Knowledge. Patient knowledge was assessed using disease-specific questionnaires administered after the use of a decision aid or shared decision making process.

3.3.7 Patient Engagement and Participation

Patient engagement and participation in healthcare refers to a patient's interest and capability to participate in their care in ways that reflect the patient's needs and preferences and for the purpose of improving person-centered health outcomes.[67] The measure constructs we include in the Inventory to assess patient engagement and participation are patient activation,[68] patients' participation in the decision making process,[69] patient empowerment,[70] and perceptions of the patient-clinician communication.

Measuring Patient Activation. Patient activation was assessed using the Patient Activation Measure,[68] which assesses patient knowledge, skill, and confidence in self-management.

Measuring Patient Participation in Decision Making Process. Several tools were reported to assess participation in decision making, including the Satisfaction with Decision-Making Process Scale;[71] Satisfaction with the Process of Making a Treatment Decision Scale;[72] Satisfaction with Decision Scale;[69] the Clinical Decision Making Involvement and Satisfaction, Patient Version (CDIS-P);[73] and the Decision Attitude Scale.[74] Additionally, some researchers reported assessing participation in care planning using qualitative surveys.

Measuring Patient Empowerment. Researchers described using the Patient Empowerment Scale to assess a patient's level of confidence in their ability to make decisions about their care and involvement in the decision making process. Researchers used the scale in both its standard form as well as disease-specific adaptations.[70]

Measuring Patient-Clinician Interaction. Approaches to measure this construct include qualitative data collection, observer-reporter techniques, as well as the Art of Medicine Questionnaire[70] and the Quality of Communication Questionnaire.[70]

3.3.8 Shared Decision Making Processes

Shared decision making has been defined as "an approach where clinicians and patients share the best available evidence when faced with the task of making decisions, and where patients are supported to consider options, to achieve informed preferences."[75] The measure constructs that describe shared decision making processes include decisional conflict and decision regret—commonly studied outcomes of patient decision aids—as well as aspects of the patients' perceptions of the decision made (e.g., decision regret,[66] confidence in decision,[76]effectiveness of the shared decision making process,[77] informed choice[61]).

Measuring Decision Conflict. To assess decision conflict, implementers report using the Decisional Conflict Scale.[78]

Measuring Decision Regret. Implementers report using a decisional regret scale[79] to measure regret.

Measuring Patients' Perceptions of the Decision Making Process. A number of instruments exist to assess different aspects of the patients' perceptions of shared decision making processes, such as the 9-item Shared Decision Making Questionnaire (SDM-Q-9),[80] CollaboRATE,[81,82] the Combined Outcome Measure for Risk Communication and Treatment Decision Making Effectiveness (COMRAD),[83] the Shared Decision-Making Process Scale,[84] Marteau's Informed Choice Scale,[61] the CDIS-P, and multiple versions of the OPTION (observing patient involvement) scale.[85]

3.3.9 Clinician Attitudes and Beliefs

In the Inventory, clinician attitudes and beliefs refer to the clinicians' perceptions of how the CDS will impact care processes and the clinical encounter. Researchers have identified clinician attitudes and beliefs as one factor that has an impact of the uptake of CDS. For example, clinicians' attitudes towards alerts depends on how alerts are displayed (i.e., intrusive or interruptive) during workflow.[42]

Measuring Attitudes and Beliefs. Researchers reported using a combination of qualitative interviews with end users and intervention-specific questionnaires to understand clinician perceptions of the impact of CDS on clinical practice and the physician-patient relationship,[47] and organizational factors such a social pressure.[14,47]

3.3.10 CDS Costs

In the Inventory, we only document study findings that report the direct costs related to the CDS technology. These direct costs include development costs, human resources, hardware and software costs, operations, and maintenance costs.[15]

Measuring CDS Technology Costs. Researchers used direct inpatient and emergency department costs as a proxy for estimating CDS technology costs.[86]

4. Evaluating PC CDS Performance: Measurement Considerations and User Scenarios

The Inventory organizes measures and measurement approaches reported from a range of CDS implementations (e.g., alerts, computerized physician order entry [CPOE], info buttons, decision aids, and patient portals). Implementers can use the information contained in the Inventory to identify measures for examining implementation design, development, implementation, and use. Below, we provide considerations and user scenarios to inform assessments of PC CDS performance.

4.1 Measurement Considerations

Expert input to the Inventory uncovered six broad considerations to apply when identifying measures to evaluate PC CDS implementations: 1) clinical context and goals of the PC CDS, 2) patient-centered measures, 3) use of validated tools, 4) feasibility, 5) continuous performance assessment, and 6) unintended consequences. These considerations, in combination with clinical and patient-centered outcomes, can contribute to a better use of measurement approaches to evaluate PC CDS initiatives.

Below are further details on these measurement considerations.

- **Clinical Context and Goals of the PC CDS.** Understanding the clinical care processes that the CDS aims to change provides the foundation on which to develop an evaluation and measurement strategy. Developing a logic model[87,88] to explain how a PC CDS tool can improve care processes, and ultimately health outcomes, can help implementers determine what to measure given their intervention-related goals. These activities should also inform baseline data collection for the purpose of conducting pre-post implementation studies.
    - Baseline data can include information collected during planning and needs assessment stages of an intervention, such as the prevalence and clinical severity of a problem, identification of clinical or quality improvement gaps, the target care process, and the target clinician and/or patient populations. For example, CDS designed to improve adherence to blood glucose monitoring for patients with diabetes could include a baseline and target rate of adherence.
    - The clinical context can inform goal identification and PC CDS design. Understanding both the clinical epidemiology of a clinical scenario and the substantiating evidence underlying the clinical guidance can help determine the desired process and clinical outcomes and application

of the CDS Five Rights to support interventions that provide the right information, to the right people, in the right formats, through the right channels, at the right times.[7]

- **Patient-centered Measures.** Given the nascency of the PC CDS literature, implementers and evaluators should work diligently to include patient-centered measures in their assessments. Recognizing these measures are less commonly used and reported in the literature, implementers should work with patient collaborators to identify measures that support assessment of patient lifeflow integration.
- **Use of Validated Tools.** To improve standard reporting and comparison across CDS implementations at different healthcare organizations, implementers should consider using validated instruments, when available, and measurement approaches with well documented specifications for reproducibility.
- **Feasibility.** In planning for evaluation, implementers should consider data and resource availability when selecting among the available performance measures, particularly as some measurement approaches are more time-intensive.
- **Continuous Performance Assessment.** The extent to which PC CDS becomes part of routine organizational practice and culture can serve as a signal of implementation success and sustainability.[19] Conversely, implementers should develop plans for continuous performance feedback and maintenance audits to monitor that CDS rules are consistent with current guidelines and to assess whether to retire a PC CDS.
- **Unintended Consequences.** In practice, healthcare organizations deploy multiple CDS tools simultaneously. When introducing a new PC CDS, implementation should identify measures for assessing the unintended consequences of implementation and use, including reviews to ensure EHR system changes and updates do not impact CDS rules.[89]

4.2 User Scenarios

This Inventory is intended for a wide variety of potential users with different perspectives and PC CDS related goals. Potential users range from community hospitals to academic medical centers, researchers, health system informatics leadership, care team members, quality improvement teams, and patient partners, among others.

To help users identify what to measure and how to measure it in common situations, this user guide presents illustrative user scenarios. These four user scenarios, developed with input from the TEP and Workgroup, are purposely intervention-agnostic. They were designed to be representative of common PC CDS implementation and research evaluation goals. For each user scenario, we identify several potential users; however, in practice, the potential users will differ by healthcare organization. In the following section, we present the results of a stakeholder-driven exercise to identify measure constructs and measurement tools and approaches that could be used to address each user scenario. These user scenarios, and the example measures, are provided as illustrative examples and intended to serve as a starting point to navigating the inventory and measure selection.

USER NOTES:

- The assessment of clinical outcomes, population health management, quality improvement and safety, risk management, and cost-effectiveness is outside of the scope of the PC CDS Performance Measurement Inventory. However, many of these outcomes are described in a companion CDSiC resource: Patient-Focused Outcome Measures for Patient-Centered CDS.
- Much of the existing research on CDS measurement focuses on clinician-facing CDS. Thus, the example measures skew toward alerts and other clinician-facing CDS. This represents a significant PC CDS measurement gap. Users are encouraged to work with patient collaborators to identify and include patient-centered measures in PC CDS evaluation.

4.2.1 Implementation User Scenarios

As described in this user guide, evaluating PC CDS design, development, implementation, and use is critical to understanding, optimizing, and scaling intervention impact. The first three user scenarios focus on common PC CDS implementation assessment goals. The final user scenario describes a common research goal.

- **User Scenario 1.** Evaluation of the performance of a PC CDS tool. Five measure categories were identified as key areas of measurement that can be included in an evaluation of PC CDS performance (**Exhibit 6**).

Exhibit 6. User Scenario 1 Sample Measures

User Scenario 1: Evaluate the performance of an evidence-based PC CDS intervention.

Potential Users: Community hospital, academic medical center, or clinical care team member; front-line clinician informatician; health system informatics leadership; procurement team; risk manager; patient partner

Performance Measurement Category	Example Measure Constructs Assessed	Example Measure and Measurement Approach
User-centered Design	• Satisfaction with user-computer interface	• Questionnaire for User Interface Satisfaction (QUIS)
Reach	• Active users	• EHR data: Number of active users of tool, by user type
Adoption	• Alert acceptance rate	• EHR data: Number of alerts accepted over total number alerts fired
	• Alert override rate	• EHR data: Number of alerts overridden over total number of alerts fired
CDS Implementation Integrity	• Alert accuracy	• EHR data: Number of false positive alerts
User Satisfaction	• User satisfaction	• System Usability Scale (SUS)

- **User Scenario 2.** Establish criteria and create monitoring tools to support continuous PC CDS maintenance. Four measure categories were identified as important to consider when establishing an approach to assessing for continuous PC CDS maintenance (**Exhibit 7**).

Exhibit 7. User Scenario 2 Sample Measures

User Scenario 2: Establish criteria and create monitoring tools to support continuous PC CDS maintenance.

Potential Users: Community hospital or clinical care team member; front-line clinician informatician; health system informatics leadership; risk manager; digital transformation team; quality improvement team

Performance Measurement Category	Example Measure Constructs Assessed	Example Measure and Measurement Approach
Information Quality	• Alert sensitivity	• EHR data: Alert positive rate (e.g., correct diagnosis)
	• Alert specificity	• EHR audit log review data: Alert negative rate (appropriate care recommendation)
Adoption	• Number of portal messages sent/received between the patient/caregiver and care team leading to clinical resolution	• Patient portal audit
	• Alert override rate	• EHR data: Number of alerts overridden over total number of alerts fired
User Satisfaction	• User satisfaction	• System Usability Scale (SUS)
Workflow Integration	• Efficiency	• Ethnographic observation, interviews, focus groups to identify the use of workarounds, or informal temporary practices for handling exceptions to normal workflow
	• Impact on clinician workflows	• EHR data: Number of reminders received per physician

- **User Scenario 3.** Assess a PC CDS intervention with a patient-focused lens and ensure that patient-centered measures are included in these efforts. Four measure categories are highlighted as potential starting points for approaching evaluation of PC CDS with a patient-facing component: usability, user satisfaction, patient engagement and participation, and shared decision making processes (**Exhibit 8**). Additional measure considerations for assessing the patient perspective include clarity of the decision support and health and digital literacy.

Exhibit 8. User Scenario 3 Sample Measures

User Scenario 3: Assess a PC CDS with a patient-focused lens, and ensure that patient-centered measures are included in these efforts. **Potential Users:** Patient partner; clinical/informatics/health services researcher; community hospital or clinical care team member; user experience team		
Performance Measurement Category	**Example Measure Construct Assessed**	**Example Measure and Measurement Approach**
Usability	• Willingness of patient to recommend the PC CDS to others	• Net Promoter Score
	• User-centered design principles	• Nielsen Heuristic Principles
User Satisfaction	• User satisfaction	• System Usability Scale (SUS)
Patient Engagement and Participation	• Patient activation	• Patient Activation Measure (PAM)
Shared Decision Making Processes	• Patient involvement in shared decision making process	• Clinical decision making involvement and satisfaction, patient version (CDIS-P) • OPTION Scale • SDM-9 Scale

4.2.2 Research User Scenario

Studying and disseminating findings from PC CDS evaluations can help implementers improve PC CDS design and implementation. It can also support scaling effective PC CDS.

- **User Scenario 4**. Publish study results and consider what measures support the generalizability of findings. Four measure categories were identified to support the consistent reporting of intervention results (**Exhibit 9**).

Exhibit 9. User Scenario 4 Sample Measures

User Scenario 4: Publish study results and consider what measures support the generalizability of findings. **Potential Users:** Academics; clinical/informatics/health services researcher; health policy analyst		
Performance Measurement Category	**Example Measure Construct Assessed**	**Example Measure and Measurement Approach**
	• Leadership support	• Degree of support from senior leaders and clinical champion (approach not specified)

Performance Measurement Category	Example Measure Construct Assessed	Example Measure and Measurement Approach
Organizational Factors	• Resource availability	• Resources available to support the implementation of the health IT, but also the IT infrastructure that can enable it (e.g., the number of terminals in each location)
Adoption	• Firing rate	• EHR data: Number of alerts (1) alerts per patient encounter, (2) alerts per inpatient-day, (3) alerts per 100 orders, and (4) alerts per unique clinician days
	• Care team use	• Proportion of visits in which the application was opened
Alert Fatigue	• Desensitization	• EHR data: Proportion of repeated alerts, defined as alerts presented to the same clinician for the same patient in the same year
	• Think time	• EHR data: Time interval between appearance of the alert and completion of the selected actions
	• Cognitive overload	• EHR data and Johns Hopkins Aggregated Diagnosis Groups (ADG) algorithm: Alerts received per encounter and comorbidity index of the clinician's patients
User Satisfaction	• User satisfaction	• System Usability Scale (SUS)

5. Measure Gaps and Limitations: Areas for Future PC CDS Measurement Research and Implementation

The Inventory provides an important step toward more standard measurement of PC CDS performance. More consistent measurement can improve the PC CDS evidence base and lead to guidance on what factors measurably improve implementation and clinical outcomes.

5.1 Measure Gaps and Recommendations

In the process of building the Inventory, we identified measurement gaps in two domains: 1) gaps in the quality of evidence, and 2) gaps related to specific measures and outcomes. Many of the systematic reviews and meta-analyses included in our scoping review found that the majority of the evidence related to CDS performance was rated as "low quality" or at "high risk of bias." To improve the evidence base around PC CDS implementation, studies that utilize robust analytic approaches, including prospective analysis with appropriate study designs, such as power analysis, long-term follow up, and analytic methods, are needed to demonstrate improvements in healthcare process outcomes. Assessments of measure quality, including fitness-for-use, reliability, and clinical significance are

lacking. Implementers can make substantial contributions to our understanding of PC CDS effectiveness by introducing measures that specifically assess the patient's perspective and patient-centered factors of PC CDS implementation in their assessment of CDS performance. Furthermore, patient-centered quality measures related to decision support (e.g., decision documentation, meeting patient goals, developing care plans), are emergent. These represent important areas for future research and will help build the evidence base around the development and use of meaningful measures that can support actionable changes in PC CDS design and implementation that result in positive outcomes for patients.

There are also gaps in specific measures and outcomes used to assess the three implementation phases of design, use, and results. These gaps point to areas of research needed to advance the field and enhance our understanding of the types of PC CDS that lead to improvements in person-centric care. **Exhibit 10** presents the identified measure and outcome gaps, as well as recommendations for future PC CDS research to enhance our understanding of effective PC CDS.

Exhibit 10. PC CDS Performance Measurement Gaps and Recommendations

Gap	Recommendation
What PC CDS Did You Design?	
Organizational Factors: Measures for leadership support and resource availability were identified; however, there is a lack of measures to assess the inter-related human and organizational factors that can lead to implementation success.	• Future studies should measure the impact of PC CDS context on implementation strategy.[23]
Feasibility: Feasibility was identified as a useful measure to aid in the selection of PC CDS. However, this review identified a lack of measures to assess implementation feasibility.	• Develop standard measures and approaches for assessing PC CDS implementation feasibility. These, or validated proxy measures, could help implementers understand the totality of resources needed to support successful implementation.
Standards Conformity: While we identified studies that report whether an interoperability or CDS standard (e.g., HL7, FHIR, CDS Hooks, LOINC, SNOMED, etc.) was used, no measures were identified that assess the degree to which these standards support PC CDS artifacts that can be shared across organizations.	• Develop standard measures for reporting conformance with a set of interoperability standards that implementers can use to determine what resources are needed to support local implementation.

Gap	Recommendation
What PC CDS Did You Use?	
Adoption of Patient-facing PC CDS: Few studies report on use of PC CDS by patients. Existing studies focus on patient portal use. Yet these studies are limited and present inconsistent results, often due to the use of non-standardized terminology related to portal features and implementation and limited analysis of patient portal usage data.	• Use standardized evaluation frameworks and measures to strengthen comparisons of patient portal implementation and outcomes.[70] For example, a taxonomy of patient portal functionalities could support standardized description of portal features and terminology, which can enable comparing and aggregating results across interventions.[70] Analyze patient portal[20] and app use to identify relationships between usage and patient outcomes to understand what qualifies as meaningful use.
Patient Lifeflow Integration: Most studies fail to consider the relationship and gaps between patient health-related activities in patients' daily lives and activities within the clinical context, prohibiting design of collaborative health technologies that can fill these gaps.	• Conduct workflow studies that are patient-oriented; include both clinical and daily living settings, and include both process and structure measures. • Develop methods to capture health-related activities across clinical and daily living settings.[42] • Develop, validate, and use measures to assess cognitive burden for patients. • Conduct studies to better understand what information is most valuable to patients to manage their own care, and why.
Patient-centric Message Fatigue. A dearth of information exists regarding the assessment and impact of repeated messages and reminders on patients from using patient-facing CDS.	• Develop standardized measures and approaches for assessing message fatigue from the patient perspective. Data collection approaches should limit burden for patients.
Patient Attitudes and Beliefs. While a few studies explore clinicians' perceptions of how CDS will impact care processes and the clinical encounter, there are no analogous measures that aim to understand patients' attitudes towards the use of PC CDS as a tool to improve care.	• Conduct studies to understand patients' willingness and readiness to use PC CDS to manage their care, facilitate shared decision making, and maintain health. Ensure study design includes measures that assess the extent to which data availability (e.g., within a patient portal) adequately supports patients to manage their own care. Use study results to guide patient engagement strategies and potential resource development.
PC CDS Uptake: System uptake is a seldom reported measure of CDS effectiveness in CDS clinical trials, and when reported, uptake was low.[23]	• Limited intervention uptake represents a major and potentially modifiable barrier to overall CDS effectiveness. Efforts should be made to encourage studies to report uptake to enhance learning and strategies to optimize this key parameter.

Gap	Recommendation
Alert Overrides: While alert fatigue is an oft-cited barrier to implementation, less is understood regarding the collection and meaningful use of alert override data.	• Measures and approaches to evaluating the reasons for alert overrides are needed to reduce the number of inappropriate alerts. • Research on how the integration of patient-specific factors can reduce fatigue,[90] including how to limit the number of within-patient alert repeats, is warranted.[50]
What Were the Results?	
Fairness and Equity: Measures of fairness and equity were identified as key measure constructs to ensure PC CDS improves health equity. While some studies acknowledge the potential impact of CDS on health disparities, few included primary or secondary outcomes to measure this impact.	• Develop standard measures and approaches for assessing the impact of PC CDS on health equity. Measures that examine the extent to which PC CDS tools consider the social context, economic context, education, physical infrastructure, and healthcare context of the end user should be prioritized.
CDS Cost: There are limited literature reporting on the direct costs associated with human resources, hardware and software costs, operations, and maintenance costs of CDS.	• Collect and report costs related to CDS implementation. Researchers should explore the use of economic variables to assess the costs to patients using patient-facing CDS.

5.2 Inventory Limitations

The Inventory has several limitations. First, while the Inventory catalogues an extensive list of performance measures and measurement approaches reported in the literature, the list is not exhaustive. We may not have captured all performance measures in use, in part, due to limited reporting of measures used in real-world implementations. Furthermore, the scoping review leveraged a large body of systematic reviews as a primary data source, which may have limited our identification of the full breadth of measures researchers report using.

Second, our approach to inventory development focused on identifying unique performance measures. As a result, the Inventory does not include an assessment of which measures are commonly reported in the literature, nor the quality of the measures. This limits the guidance on which measures to select for a particular evaluation need. Instead, we rely on the expert opinions of the stakeholders engaged in the development of this user guide to provide input on the user scenarios and identification of measure categories relevant to the user scenario goals. To our knowledge, assessments regarding the quality of measures are lacking. Here too, we rely on expert input which prioritizes use of validated instruments as one approach to addressing this evidence gap.

Third, there is variability in the design of the tools and approaches used to measure CDS performance. For the Inventory, we have grouped similar measures thematically. However, this signals a need for more standardized measurement and reporting.

Appendix A. Methods

The PC CDS Measurement Inventory and this User Guide were developed collaboratively through extensive interactions among the CDSiC Scaling, Measurement, and Dissemination Workgroup leads, Workgroup members, Technical Expert Panel (TEP) members, and the Workgroup support team. The methods that guided tool development within this collaboration are described below.

Research Questions

The following research questions informed development of the Inventory:

1. What is the current state of CDS intervention development, implementation, performance, and value measurement (i.e., specific measures and measurement approaches)?
    a. What measurement approaches exist for CDS tools that are patient-facing, or both provider- and patient-facing?
    b. Where are the gaps?
2. What is the current state of patient-oriented process measures for PC CDS tools (e.g., patient activation, patient interaction with CDS, decision quality)? Where are the gaps?
3. What is the current state of PC CDS measure use?
4. How is the impact of patient/user-centeredness on CDS intervention success currently measured?

Scoping Literature Review

We conducted a scoping review of peer-reviewed literature on CDS measurement, PC CDS adoption, shared decision making processes and use of patient decision aids, and the impacts of CDS use on care team workflows and patient lifeflows. We searched PubMed to identify peer-reviewed literature in a multi-phased approach. We conducted three searches related to systematic reviews of CDS studies, CDS evaluation and implementation, and CDS implementation and process outcomes (See **Exhibit A1**). After de-duplication, our search yielded 659 peer-reviewed articles. We conducted two levels of screening—a title/abstract review and a full-text review. At each level, we assessed whether the reviewed records appeared to meet our eligibility criteria (see **Exhibit A2**).

Records deemed eligible at the title/abstract level were screened again at the full-text review. We conducted a full-text review of 120 peer-reviewed articles identified from the PubMed searches. We then determined the final list of eligible records for data abstraction, and for ineligible records, documented the reason(s) they were excluded. In total, 53 articles were included from the literature searches performed.

Additionally, we reviewed articles that were recommended by Workgroup members and CDSiC project team members. We included five recommended articles after screening. During the literature review process for two other CDSiC Scaling, Measurement, and Dissemination Workgroup products, we flagged articles relevant to this tool; we included two peer-reviewed articles through this

mechanism. Finally, we included two additional articles identified through snowball sampling of included literature.

In total, we screened 668 peer-reviewed journal articles and included 62 articles.

Exhibit A1. Key Search Terms for the Scoping Literature Review

#1 CDS Search String	#2 Evaluation String	#3 Implementation Process Outcome String	#4 PC CDS Process Outcomes String
"clinical decision support"[tiab] OR "Decision Support Systems, Clinical"[Mesh] OR “Medical Order Entry Systems” [Mesh] OR "Clinical Decision-Making"[Majr] OR "Decision Making, Computer-Assisted"[Majr] OR "Clinical Decision Rules"[Majr] OR Decision Support Systems, Clinical / standards [Mesh]	evaluat*[tiab] OR "Process Assessment, Health Care"[Mesh] OR “Reproducibility of Results” [Mesh] OR “Cost-benefit analysis” [Mesh] OR Randomized controlled Trials as Topic OR “Program Evaluation” [Mesh] OR “user testing” [tiab] OR “usability” [tiab] OR “evaluation criteria” [tiab] OR “utility” [tiab]	“human centered design" [tiab] OR “User-Computer Interface” [Mesh] OR “Reminder Systems” [Mesh] OR “Time Factors” [Mesh] OR “Medical Order Entry Systems*” [Mesh] OR “Workflow” [Mesh] OR “user workload”[tiab] OR “acceptability of Health Care” [tiab] Or “acceptability” [tiab] OR “Efficiency” [Mesh] OR “satisfaction” [tiab] OR “provider satisfaction” [tiab] OR “Alert Fatigue, Health Personnel” [Mesh] OR “Task Performance and Analysis” [Mesh] OR “level of comfort” [tiab] OR “ease of use” [tiab] OR “workflow burden”	“decision quality”[tiab] OR “decision making” [Mesh] OR “Patient Satisfaction” [Mesh] OR “Health Knowledge, Attitudes, Practice” [Mesh] OR “Choice Behavior” [Mesh] OR “cognitive load” [tiab] OR “fatigue” [Mesh] OR “alert fatigue” [tiab] OR “decisional conflict” [tiab] OR “Patient Medication Knowledge” [Mesh] OR “patient burden” [tiab] OR “care team burden” [tiab]

Exhibit A2. Literature Search Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• Published/developed in 2012 or later for systematic review search, 2017 or later for peer-reviewed literature search. • Peer-reviewed literature including literature reviews, qualitative studies, implementation studies, viewpoints, and commentaries. • Focuses on the use or implementation of clinical decision support, health technology, or person-centered care implementation in the United States. • Describes measures - including measurement and evaluation frameworks, approaches, or guidance - for evaluating steps of the PC CDS development and implementation process, including performance and value measures and patient-oriented process outcomes and experience measures (e.g., patient satisfaction, cognitive load, decisional conflict, patient burden, patient health knowledge, attitudes, or practices).	• Does not address a clinical decision support intervention or technologies that could be applied to improve PC CDS. • Does not discuss measures for evaluating CDS development, implementation, performance, value, or process outcomes. • Does not include human patients (e.g., veterinary studies; algorithms or provider-focused tools that do not involve some element of patient interaction). • Source is not peer-reviewed literature (e.g., grey literature, blogs, books, news articles, discussion forum, webinars). • Describes clinical outcomes measures, including measures related to population health. • Not United States-based.

Analysis and Synthesis

Three independent reviewers extracted the following data from the included literature from the scoping review: implementation setting, users (e.g., clinicians, patients, and caregivers), measurement domain, measure description, and measurement guidance. Reviewers identified measures, measure definitions, and measurement guidance from data abstraction and organized them into corresponding implementation phases (e.g., design, use, results), PC CDS measurement categories, and measurement constructs in an inventory spreadsheet. For each measure in the spreadsheet, information about the measure, including measure description, measure properties, measure specifications, and measure source is provided.

Informed by measures and measurement guidance identified in the literature review, user scenarios were developed for inclusion in the final product. The illustrative user scenarios include instructions on how to use the Guide to address the questions posed within the scenario, including key measures.

Technical Expert Panel

To inform and guide product development, the Workgroup convened a 12-member, multidisciplinary TEP who represented various stakeholder perspectives, including health system informatics leaders, EHR and CDS developers, and a patient partner, to provide input on PC CDS intervention use cases and measure selection. The TEP met three times throughout the product development process. The first meeting was held in late January 2023 to share initial findings from the literature review and

discuss user scenario selection. The second meeting was held in April 2023 to discuss the initial list of measures and revised user scenarios for inclusion in the Inventory. The final TEP meeting was held in June 2023, where TEP members provided final feedback on the PC CDS Measurement Inventory.

Measurement Inventory Development

The organization of the PC CDS Performance Measurement Guide and Inventory was developed through an iterative process with input from the CDSiC Scaling, Measurement, and Dissemination Workgroup and Leads and the TEP.

User Scenario Development

The user scenarios were also developed through an iterative stakeholder-driven process. To inform measure selection for each illustrative user scenario, we engaged both the CDSiC Workgroup and the TEP in a two-stage prioritization activity. First, Workgroup and TEP members were asked to identify key measurement categories for each scenario. From this list of measurement categories, we selected example measures and measurement tools from the Inventory. In the second phase, we sought input from the Workgroup and TEP members to ensure the identified measures and measurement tools selected were representative.

References

[1] Agency for Healthcare Research and Quality Clinical Decision Support Innovation Collaborative. Infographic: Patient-Centered Clinical Decision Support Explained. Accessed July 14, 2023. Retrieved from https://cds.ahrq.gov/cdsic/patientcentered.

[2] Sittig DF, Boxwala A, Wright A, et al. A lifecycle framework illustrates eight stages necessary for realizing the benefits of patient-centered clinical decision support*. J Am Med Inform Assoc.* 2023 Jul 6:ocad122. doi:10.1093/jamia/ocad122.

[3] Clinical Decision Support Innovation Collaborative. Measuring PC CDS Performance: A Unified Framework. 2023. Prepared under Contract No. 75Q80120D00018.

[4] Bright TJ, Wong A, Dhurjati R, et al. Effect of clinical decision-support systems: A systematic review. *Ann Intern Med*. 2012;157(1):29-43. doi:10.7326/0003-4819-157-1-201207030-00450

[5] Cohen DJ, Keller SR, Hayes GR, Dorr DA, Ash JS, Sittig DF. Integrating patient-generated health data into clinical care settings or clinical decision-making: Lessons learned from Project HealthDesign. *JMIR Hum Factors.* 2016;3(2):e26. doi:10.2196/humanfactors.5919

[6] Chen W, Howard K, Gorham G, et al. Design, effectiveness, and economic outcomes of contemporary chronic disease clinical decision support systems: a systematic review and meta-analysis. *J Am Med Inform Assoc*. 2022;29(10):1757-1772. doi:10.1093/jamia/ocac110

[7] Osheroff JA, Teich JA, Levick D, et al. *Improving Outcomes with Clinical Decision Support: An Implementer's Guide.* 2nd ed. Chicago, IL: HIMSS; 2012.

[8] Kawamoto K, Del Fiol G, Lobach DF, Jenders RA. Standards for scalable clinical decision support: need, current and emerging standards, gaps, and proposal for progress. *Open Med Inform J*. 2010; 4:235-244. doi:10.2174/1874431101004010235

[9] United States General Services Administration. Usability.gov. User-Centered Design Basics. Retrieved from https://www.usability.gov/what-and-why/user-centered-design.html.

[10] Yen PY, Sousa KH, Bakken S. Examining construct and predictive validity of the Health-IT Usability Evaluation Scale: Confirmatory factor analysis and structural equation modeling results. *J Am Med Inform Assoc* 2014;21(e2):e241–e248

[11] Lewis J, James R. IBM Computer Usability Satisfaction Questionnaires: Psychometric evaluation and instructions for use. *Int J Hum Comput Interact*. 1995;7(1):57-78. 10.1080/10447319509526110

[12] Nielsen Norman Group. 10 Usability Heuristics for User Interface Design. Accessed July 14, 2023. Retrieved from https://www.nngroup.com/articles/ten-usability-heuristics/

[13] Lin YL, Guerguerian AM, Tomasi J, Laussen P, Trbovich P. Usability of data integration and visualization software for multidisciplinary pediatric intensive care: A human factors approach to assessing technology. *BMC Med Inform Decis Mak.* Aug 14 2017;17(1):122. doi:10.1186/s12911-017-0520-7

[14] Liu S, Reese TJ, Kawamoto K, Del Fiol G, Weir C. A theory-based meta-regression of factors influencing clinical decision support adoption and implementation. *J Am Med Inform Assoc*. 2021;28(11):2514-2522. doi:10.1093/jamia/ocab160

[15] Byrne CM, Pan EC, Russell C, Finley S, Rippen HE. Applying an organizational framework for health information technology to alerts. *AMIA Annu Symp Proc.* 2012;2012:67-76.

[16] Wright A, Aaron S, McCoy AB, et al. Algorithmic Detection of Boolean Logic Errors in Clinical Decision Support Statements. *Appl Clin Inform*. 2021;12(1):182-189. doi:10.1055/s-0041-1722918

[17] Thayer JG, Ferro DF, Miller JM, et al. Human-centered development of an electronic health record-embedded, interactive information visualization in the emergency department using fast healthcare interoperability resources. *J Am Med Inform Assoc*. 2021 Jul 14;28(7):1401-1410. doi:10.1093/jamia/ocab016.

[18] Jauk S, Veeranki SPK, Kramer D, et al. External validation of a machine learning based delirium prediction software in clinical routine. *Stud Health Technol Inform.* May 16 2022;293:93-100. doi:10.3233/shti220353

[19] Glasgow RE, Harden SM, Gaglio B, et al. RE-AIM Planning and Evaluation Framework: Adapting to New Science and Practice With a 20-Year Review. *Front Public Health*. 2019;7:64. doi:10.3389/fpubh.2019.00064

[20] Beal LL, Kolman JM, Jones SL, Khleif A, Menser T. Quantifying patient portal use: Systematic review of utilization metrics. *JMIR.* 2021;23(2):e23493.

[21] Van Dort BA, Zheng WY, Sundar V, Baysari MT. Optimizing clinical decision support alerts in electronic medical records: A systematic review of reported strategies adopted by hospitals. *J Am Med Inform Assoc*. 2021;28(1):177-183. doi:10.1093/jamia/ocaa279

[22] Carroll C, Patterson M, Wood S, Booth A, Rick J, Balain S. A conceptual framework for implementation fidelity. *Implement Sci.* 2007 Nov 30;2:40. doi:10.1186/1748-5908-2-40

[23] Kouri A, Yamada J, Lam Shin Cheung J, Van de Velde S, Gupta S. Do providers use computerized clinical decision support systems? A systematic review and meta-regression of clinical decision support uptake. *Implement Sci*. 2022;17(1):21. Published 2022 Mar 10. doi:10.1186/s13012-022-01199-3

[24] Poly TN, Islam MM, Yang HC, Li YJ. Appropriateness of overridden alerts in computerized physician order entry: Systematic review. *JMIR Med Inform.* 2020;8(7):e15653. doi:10.2196/15653

[25] Duman-Lubberding S, van Uden-Kraan CF, Jansen F, et al. Feasibility of an eHealth application "OncoKompas" to improve personalized survivorship cancer care. *Support Care Cancer*. 2016;24(5):2163-2171. doi:10.1007/s00520-015-3004-2

[26] Wyatt KD, Branda ME, Anderson RT, et al. Peering into the black box: A meta-analysis of how clinicians use decision aids during clinical encounters. *Implement Sci*. 2014;9:26. doi:10.1186/1748-5908-9-26

[27] Kassakian SZ, Yackel TR, Gorman PN, Dorr DA. Clinical decisions support malfunctions in a commercial electronic health record. *Appl Clin Inform.* 2017 Sep 6;8(3):910-923. doi:10.4338/ACI-2017-01-RA-0006

[28] Cain C, Haque S. Organizational workflow and its impact on work quality. In: Hughes RG, eds. *Patient Safety and Quality: An Evidence-Based Handbook for Nurses.* Rockville, MD: Agency for Healthcare Research and Quality; 2008. Chapter 31.

[29] Orenstein EW, Kandaswamy S, Muthu N, et al. Alert burden in pediatric hospitals: A cross-sectional analysis of six academic pediatric health systems using novel metrics. *J Am Med Inform Assoc.* 2021;28(12):2654-2660. doi:10.1093/jamia/ocab179

[30] Zheng K, Ratwani RM, Adler-Milstein J. Studying workflow and workarounds in electronic health record-supported work to improve health system performance. *Ann Intern Med*. 2020;172(11 Suppl):S116-S122. doi:10.7326/M19-0871

[31] Jing X, Cimino JJ, Del Fiol G. Usability and acceptance of the librarian infobutton tailoring environment: An open access online knowledge capture, management, and configuration tool for OpenInfobutton. *J Med Internet Res*. 2015;17(11):e272. doi:10.2196/jmir.4281t

[32] Teixeira M, Cook DA, Heale BSE, Del Fiol G. Optimization of infobutton design and implementation: A systematic review. *J Biomed Inform*. 2017;74:10-19. doi:10.1016/j.jbi.2017.08.010

[33] Agency for Healthcare Research and Quality. Workflow Assessment for Health IT Toolkit. NASA Task Load Index. Accessed July 14, 2023. Retrieved from https://digital.ahrq.gov/health-it-tools-and-resources/evaluation-resources/workflow-assessment-health-it-toolkit/all-workflow-tools/nasa-task-load-index

[34] Learning Health System (LHS) Collaborative and Veterans Administration (VA). Generic Health Service Blueprint, Version 0.5. Accessed January 24, 2023. Retrieved from https://docs.google.com/spreadsheets/d/1m5cGIKkJFjian4W0PP8-5Wt5xgh8VCvlyGrTDxH8DyM/edit#gid=1651917924

[35] Agency for Healthcare Quality and Research. Patient Journey and Service Blueprint How Tos. Accessed on April 4, 2023. Retrieved from https://cmext.ahrq.gov/confluence/display/PUB/Patient+Journey+and+Service+Blueprint+How+Tos

[36] Chan AJ, Chan J, Cafazzo JA, et al. Order sets in health care: A systematic review of their effects. *Int J Technol Assess Health Care*. 2012;28(3):235-240. doi:10.1017/S0266462312000281

[37] International Standards Organization. 4.19 Usability in *Usability of Consumer Products and Products for Public Use — Part 2: Summative Test Method*. 2013. Retrieved from https://www.iso.org/obp/ui/#iso:std:iso:ts:20282:-2:ed-2:v1:en

[38] Knols B, Louws M, Hardenbol A, Dehmeshki J, Askari M. The usability aspects of medication-related decision support systems in the inpatient setting: A systematic review. *Health Informatics J.* 2020;26(1):613-627. doi:10.1177/1460458219841167

[39] Brooke J. SUS-A Quick and Dirty Usability Scale. Usability Evaluation in Industry. 1996 Jun 11;189(194):4-7. https://digital.ahrq.gov/sites/default/files/docs/survey/systemusabilityscale%2528sus%2529_comp%255B1%255D.pdf

[40] Lewis JR. Psychometric evaluation of the post-study system usability questionnaire: The PSSUQ. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting.* 1992;36(16):1259–1260.

[41] Holden RJ, Karsh BT. The technology acceptance model: its past and its future in health care. *J Biomed Inform*. 2010;43(1):159-172. doi:10.1016/j.jbi.2009.07.002

[42] Olakotan O, Mohd Yusof M, Ezat Wan Puteh S. A systematic review on CDSS alert appropriateness. *Stud Health Technol Inform.* 2020;270:906-910. doi:10.3233/SHTI200293

[43] Singh N, Hess E, Guo G, et al. Tablet-based patient-centered decision support for minor head injury in the emergency department: Pilot study. *JMIR Mhealth Uhealth*. 2017 Sep 28;5(9):e144. doi:10.2196/mhealth.8732

[44] Porat T, Delaney B, Kostopoulou O. The impact of a diagnostic decision support system on the consultation: Perceptions of GPs and patients. *BMC Med Inform Decis Mak.* Jun 2 2017;17(1):79. doi:10.1186/s12911-017-0477-6

[45] Peipert JD, Beaumont JL, Bode R, Cella D, Garcia SF, Hahn EA. Development and validation of the functional assessment of chronic illness therapy treatment satisfaction (FACIT TS) measures. *Qual Life Res*. 2014 Apr 24;23(3):815-824. doi:10.1007/s11136-013-0520-8

[46] Fathima M, Peiris D, Naik-Panvelkar P, Saini B, Armour CL. Effectiveness of computerized clinical decision support systems for asthma and chronic obstructive pulmonary disease in primary care: A systematic review. *BMC Pulm Med*. 2014;14(1):1-24. doi: /10.1186/1471-2466-14-189

[47] Kilsdonk E, Peute LW, Jaspers MW. Factors influencing implementation success of guideline-based clinical decision support systems: A systematic review and gaps analysis. *Int J Med Inform*. 2017;98:56-64. doi:10.1016/j.ijmedinf.2016.12.001

[48] American Board of Internal Medicine PSQ Project Co-Investigators. *Final Report on the Patient Satisfaction Questionnaire Project.* Philadelphia, PA: American Board of Internal Medicine; 1989.

[49] Kawamanto K, Flynn MC, Kukhareva P, et al. A pragmatic guide to establishing clinical decision support governance and addressing decision support fatigue: A case study. *AMIA Annu Symp Proc.* 2018;2018:624-633

[50] Ancker JS, Edwards A, Nosal S, Hauser D, Mauer E, Kaushal R; with the HITEC Investigators. Effects of workload, work complexity, and repeated alerts on alert fatigue in a clinical decision support system. *BMC Med Inform Decis Mak.* 2017 Apr 10;17(1):36. doi:10.1186/s12911-017-0430-8

[51] van der Sijs H, Aarts J, Vulto A, Berg M. Overriding of drug safety alerts in computerized physician order entry. *J Am Med Inform Assoc.* 2006;13(2):138–147. doi:10.1197/jamia.M1809

[52] Wong A, Rehr C, Seger DL, et al. Evaluation of harm associated with high dose-range clinical decision support overrides in the intensive care unit. *Drug Saf.* 2019;42:573-579. doi:10.1007/s40264-018-0756-x

[53] Schreiber R, Gregoire JA, Shaha JE, Shaha SH. Think time: A novel approach to analysis of clinicians' behavior after reduction of drug-drug interaction alerts. *Int J Med Inform*. 2017 Jan;97:59-67. doi: 10.1016/j.ijmedinf.2016.09.011

[54] Kane-Gill SL, O'Connor MF, Rothschild JM, et al. Technologic distractions (Part 1): Summary of approaches to manage alert quantity with intent to reduce alert fatigue and suggestions for alert fatigue metrics. *Crit Care Med.* 2017;45(9):1481-1488. doi:10.1097/CCM.0000000000002580

[55] Klarenbeek SE, Weekenstroo HHA, Sedelaar JPM, Fütterer JJ, Prokop M, Tummers M. The effect of higher level computerized clinical decision support systems on oncology care: A systematic review. *Cancers (Basel).* 2020;12(4):1032. doi:10.3390/cancers12041032

[56] Jenkins JA, Pontefract SK, Cresswell K, Williams R, Sheikh A, Coleman JJ. Antimicrobial stewardship using electronic prescribing systems in hospital settings: A scoping review of interventions and outcome measures. *JAC Antimicrob Resist*. 2022;4(3):dlac063. doi:10.1093/jacamr/dlac063

[57] Barnes GD, Spranger E, Sippola E, et al. Assessment of a best practice alert and referral process for preprocedure antithrombotic medication management for patients undergoing gastrointestinal endoscopic procedures. *JAMA Netw Open*. Feb 5 2020;3(2):e1920548. doi:10.1001/jamanetworkopen.2019.20548

[58] Pawloski PA, Brooks GA, Nielsen ME, Olson-Bullis BA. A systematic review of clinical decision support systems for clinical oncology practice. *J Natl Compr Canc Netw*. 2019;17(4):331-338. doi:10.6004/jnccn.2018.7104

[59] Poprzeczny AJ, Stocking K, Showell M, Duffy JMN. Patient decision aids to facilitate shared decision making in obstetrics and gynecology: A systematic review and meta-analysis. *Obstet Gynecol.* 2020;135(2):444-451. doi:10.1097/AOG.0000000000003664

[60] Martínez-Alonso M, Carles-Lavila M, Pérez-Lacasta MJ on behalf of the InforMa Group, et al. Assessment of the effects of decision aids about breast cancer screening: A systematic review and meta-analysis. *BMJ Open*. 2017;7:e016894. doi: 10.1136/bmjopen-2017-016894

[61] Larsen MB, Stokholm R, Kirkegaard P, Laursen HS, Gabel P, Andersen B. Making decisions on your own: Self-administered decision aids about colorectal cancer screening - A systematic review and meta-analyses. *Patient Educ Couns*. 2022;105(3):534-546. doi:10.1016/j.pec.2021.07.035

[62] Coronado-Vázquez V, Gómez-Salgado J, de Los Monteros JCE, García-Colinas MA. Shared decision-support tools in hospital emergency departments: A systematic review. *J Emerg Nurs*. 2019;45(4):386-393.

[63] Yen RW, Smith J, Engel J, et al. A systematic review and meta-analysis of patient decision aids for socially disadvantaged populations: Update from the International Patient Decision Aid Standards (IDPAS). *Med Decis Making*. 2021;41(7):870-896. doi:10.1177/0272989X211020317

[64] Scalia P, Durand MA, Berkowitz JL, Ramesh NP, Faber MJ, Kremer JA, Elwyn G. The impact and utility of encounter patient decision aids: Systematic review, meta-analysis and narrative synthesis. *Patient Educ Couns*. 2019;102(5):817–841. https://doi.org/10.1016/j.pec.2018.12.020

[65] Khalifa M, Magrabi F, Gallego Luxan B. Evaluating the impact of the grading and assessment of predictive tools framework on clinicians and health care professionals' decisions in selecting clinical predictive tools: Randomized controlled trial. *J Med Internet Res.* 2020;22(7):e15770. doi:10.2196/15770

[66] Mangla M, Bedair H, Chang Y, et al. Protocol for a randomised trial evaluating the comparative effectiveness of strategies to promote shared decision making for hip and knee osteoarthritis (DECIDE-OA study). *BMJ Open.* 2019;9(2):e024906. doi:10.1136/bmjopen-2018-024906

[67] Higgins T, Larson E, Schnall R. Unraveling the meaning of patient engagement: A concept analysis. *Patient Educ Couns*. 2017;100(1):30-36. doi:10.1016/j.pec.2016.09.002

[68] Sánchez B, Guijarro C, Velasco M, Vicente MJ, Galán M, Herreros B. Evaluating the efficacy of an advanced care planning program for health decisions in patients with advanced heart failure: Protocol for a randomized clinical trial. *BMC Cardiovasc Disord*. 2020 Oct 21;20(1):456. doi: 10.1186/s12872-020-01738-0.

[69] Sawka AM, Ghai S, Yoannidis T, et al. A prospective mixed-methods study of decision-making on surgery or active surveillance for low-risk papillary thyroid cancer. *Thyroid*. Jul 2020;30(7):999-1007. doi:10.1089/thy.2019.0592

[70] Ammenwerth E, Hoerbst A, Lannig S, Mueller G, Siebert U, Schnell-Inderst P. Effects of Adult Patient Portals on Patient Empowerment and Health-Related Outcomes: A Systematic Review. *Stud Health Technol Inform*. 2019;264:1106-1110. doi:10.3233/SHTI190397

[71] Légaré F, Adekpedjou R, Stacey D, et al. Interventions for increasing the use of shared decision making by healthcare professionals. *Cochrane Database Syst Rev*. 2018;7(7):CD006732. doi:10.1002/14651858.CD006732.pub4

[72] Si J, Guo R, Lu X, et al. Decision aids on breast conserving surgery for early stage breast cancer patients: A systematic review. *BMC Med Inform Decis Mak*. 2020 Oct 22;20(1):275. doi:10.1186/s12911-020-01295-8.

[73] Slade M, Jordan H, Clarke E, et al. The development and evaluation of a five-language multi-perspective standardised measure: clinical decision-making involvement and satisfaction (CDIS). *BMC Health Serv Res*. 2014;14:323. doi:10.1186/1472-6963-14-323

[74] Barr PJ, Scholl I, de Silva D. Patient-reported measures of shared decision making. In Elwyn G, Edwards A, Thompson R, eds. *Shared Decision Making in Health Care: Achieving Evidence-based Patient Choice*. 3rd ed. Oxford Academic: 2016:168-175. doi:10.1093/acprof:oso/9780198723448.003.0026

[75] Elwyn G, Coulter A, Laitner S, Walker E, Watson P, Thomson R. Implementing shared decision making in the NHS. *BMJ.* 2010;341:c5146. doi: 10.1136/bmj.c5146.

[76] Riddle DL, Sando T, Tarver T, et al. Shared Decision-Making Applied to Knee Arthroplasty: A Systematic Review of Randomized Trials. *Arthritis Care Res (Hoboken)*. 2021;73(8):1125-1133. doi:10.1002/acr.24240

[77] Sepucha KR, Scholl I. Measuring shared decision making: a review of constructs, measures, and opportunities for cardiovascular care. *Circ Cardiovasc Qual Outcomes*. 2014;7(4):620-626. doi:10.1161/CIRCOUTCOMES.113.000350

[78] O'Connor AM. Validation of a decisional conflict scale. *Med Decis Making*. 1995 Jan-Mar;15(1):25-30.

[79] Brehaut JC, O'Connor AM, Wood TJ, et al. Validation of a decision regret scale. *Med Decis Making*. 2003;23(4):281-292. doi:10.1177/0272989X03256005

[80] Kriston L, Scholl I, Hölzel L, Simon D, Loh A, Härter M. The 9-item Shared Decision Making Questionnaire (SDM-Q-9). Development and psychometric properties in a primary care sample. *Patient Educ Couns*. 2010;80(1):94-99. doi:10.1016/j.pec.2009.09.034

[81] Elwyn G, Barr PJ, Grande SW, Thompson R, Walsh T, Ozanne EM. Developing CollaboRATE: A fast and frugal patient-reported measure of shared decision making in clinical encounters. *Patient Educ Couns*. 2013;93:102-107. doi:10.1016/j.pec.2013.05.009

[82] Barr PJ, Thompson R, Walsh T, Grande SW, Ozanne EM, Elwyn G. The psychometric properties of CollaboRATE: A fast and frugal patient-reported measure of the shared decision-making process. *J Med Internet Res*. 2014;16:e2. doi.org:10.2196/jmir.3085

[83] Edwards A, Elwyn G, Hood K, et al. The development of COMRADE--a patient-based outcome measure to evaluate the effectiveness of risk communication and treatment decision making in consultations. *Patient Educ Couns*. 2003;50(3):311-322. doi:10.1016/s0738-3991(03)00055-7

[84] Valentine KD, Vo H, Fowler FJ Jr, Brodney S, Barry MJ, Sepucha KR. Development and evaluation of the Shared Decision Making Process Scale: A short patient-reported measure. *Med Decis Making*. 2021;41(2):108-119. doi:10.1177/0272989X20977878

[85] Elwyn G, Edwards A, Wensing M*,* et al*.* Shared decision making: Developing the OPTION scale for measuring patient involvement. *BMJ Quality & Safety.* 2003;12(2):93-99.

[86] Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety: A systematic review. *Arch Intern Med*. 2003;163:1409–1416

[87] W.K. Kellogg Foundation. Logic Model Development Guide. 2004, January. Accessed on July 31, 2023. Retrieved from https://www.naccho.org/uploads/downloadable-resources/Programs/Public-Health-Infrastructure/KelloggLogicModelGuide_161122_162808.pdf

[88] McLaughlin JA & Jordan GB. Logic models: A tool for telling your programs performance story. *Eval and Program Plan*. 1999; 22(1):65-72.

[89] Sittig DF, Singh H. A new sociotechnical model for studying health information technology in complex adaptive healthcare systems. *Qual Saf Health Care*. 2010;19 Suppl 3(Suppl 3):i68-i74. doi:10.1136/qshc.2010.042085

[90] McCoy AB, Waitman LR, Lewis JB, Wright JA, Choma DP, Miller RA, Peterson JF. A framework for evaluating the appropriateness of clinical decision support alerts and responses. *J Am Med Inform Assoc*. 2012;19(3):346–352. doi:10.1136/amiajnl-2011-000185