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EHR Data Quality Best Practices for Increased Scientific Acceptability: An Environmental Scan

FINAL REPORT

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Contents

Executive Summary

Although electronic health records (EHRs) are primarily used to support patient care and medical billing, their alternative use as a data source for clinical quality measures can potentially improve quality measurement. To better understand this potential, it is important to examine the current state of EHR data quality. This project aims to address the challenges that impact the development, endorsement, and implementation of healthcare performance measures that use EHR data and develop recommendations mitigating these challenges.

In the summer of 2019, the National Quality Forum (NQF) convened a multistakeholder Technical Expert Panel (TEP) to identify best practices addressing EHR data quality issues impacting the use of EHR data in electronic clinical quality measures (eCQMs). This effort is expected to improve the scientific acceptability of eCQMs and ultimately reduce provider burden when reporting to quality and reporting programs.

This report describes the methodology and findings from an environmental scan NQF conducted to summarize existing literature discussing the extent of EHR data quality issues, current practices addressing these issues and their challenges, and key stakeholders' major findings on what relevant information is currently available.

The environmental scan begins by looking at challenges of implementing eCQMs in inpatient and outpatient settings, with an examination of pertinent legislation (e.g., the Health Information Technology for Economic and Clinical Health Act of 2009) as well as current and emerging specifications and activities related to EHRs and interoperability (e.g., Fast Healthcare Interoperability Resources). The scan then looks at the post-acute care setting as an example that has not reached the same level of EHR implementation and eCQM endorsement as inpatient and outpatient settings. The Improving Medicare Post-Acute Care Transformation Act of 2014 is reviewed along with emerging practices in EHRs, interoperability, and eCQMs in long-term care hospitals, home health agencies, and other post-acute care settings.

Structured data is critical to the development, endorsement, and implementation of eCQMs, but because quality measurement is not the primary purpose of EHR systems, unstructured data is still extensively used to document important clinical information that is qualitative, provides a narrative, or varies significantly between patients. The scan looks at the role that both structured and unstructured data play in current EHR use and some different approaches—particularly natural language processing—to using unstructured data for automated healthcare quality measurement.

To date, NQF has endorsed 34 eCQMs. So, the scan looks at both the challenges that accompany eCQM development and endorsement as well as some promising and best practices that have emerged since eCQMs entered the quality landscape. This section of the scan considers multiple perspectives on challenges and opportunities, including those of measure developers, NQF staff, NQF Standing Committees, EHR vendors, and clinicians and/or researchers in healthcare settings.

Because standardization can be an important aspect of EHR data quality and eCQM development, endorsement, and implementation, the scan section of the paper concludes by reviewing four proposed frameworks for EHR data quality as well as guidance from standard setting bodies.

The intent of this scan is to be accessible to both novice and experienced measure developers, EHR implementers, data analysts, and other stakeholders. Because the language related to this topic can be extremely technical, a glossary is included to help ensure the document is useful to multiple stakeholders with varying levels of expertise.

The current state assessment from this document will set the foundation for the development of a final report to be completed in December 2020. This report will offer recommendations on how to advance EHR data in ways that support the development, endorsement, and implementation of eCQMs.

Background and Context

One of the promises of EHRs is that they may enable automated clinical quality measure reporting. EHR systems are primarily designed to support patient care and billing, not necessarily to capture data for alternative uses such as quality measurement.[1] However, since EHR data collected for patient care are often relevant for clinical quality measures, they can be reused to reduce provider burden associated with collecting and reporting data for public reporting and value-based purchasing programs.[2,3]

This project aims to address the challenges that impact the development, endorsement, and implementation of healthcare performance measures that use EHR data, and to develop recommendations mitigating these challenges. In 2019, NQF, with funding from the Unite States Department of Health and Human Services (HHS), convened a TEP to identify the causes, nature, and extent of EHR data quality issues, particularly as they relate to measure development, endorsement, and implementation. This initiative specifically focused on how well EHR data can be used to support automated clinical quality measurement. Informed by these activities, the TEP will make recommendations to HHS for best practices in assessing and improving EHR data quality to improve the development, endorsement, and implementation of measures that use EHR data. This environmental scan serves as a foundation to the overarching goal of this project by summarizing current literature about EHR data quality issues, current practices addressing these issues, and key stakeholders' major findings on currently available information.

Goals, Objectives, and Approach for the Environmental Scan

The goal of this environmental scan is to identify and summarize key findings on the causes, nature, and extent of EHR data quality issues and the impact these have on the scientific acceptability, feasibility, and use and usability of clinical quality measures. The environmental scan considers data quality issues as they relate to measure development, endorsement, and implementation.

The objectives of the scan are to identify:

- The current landscape for assessing and maximizing structured EHR data quality, particularly as it pertains to developing, testing, and implementing eCQMs in inpatient and outpatient settings as well as post-acute care (PAC) settings
- Approaches currently used to mitigate data quality challenges and how the approaches vary based on the specific data quality issue (i.e., validity, lack of structured data)
- Data needed to support development and testing of eCQMs
- Structural and organizational attributes of institutions that have successfully implemented eCQMs supported by EHRs with validated data quality
- How data quality issues have impeded endorsement of eCQMs submitted to NQF's Consensus Development Process (CDP)
- Guidance promulgated by research and standard-setting bodies to help mitigate EHR data quality issues

NQF reviewed many sources to characterize the causes, nature, and extent of EHR data quality issues, including peer-reviewed and grey literature via systematic queries of PubMed and Google Scholar. Because many of the technical specifications relevant to clinical quality measurement are not yet reflected in the peer-reviewed literature, we included additional relevant sources from Health Level Seven International (HL7), NQF, and HHS—including the Centers for Medicare & Medicaid Services (CMS) and the Office of the National Coordinator for Health information Technology (ONC)—in the scan.

Scan Results and Analysis

Implementation Challenges with eCQMs in Inpatient and Outpatient Settings

Performance measure usage in the inpatient and outpatient settings rely on a variety of data sources including claims, registry, and EHR systems. As a result of the Health Information Technology for Economic and Clinical Health Act of 2009 (HITECH Act) and the EHR Incentive Programs, 4 out of 5 office-based physicians and over 90 percent of hospitals use ONC-certified EHR systems. eCQMs were seen as a chance to take advantage of the new opportunity presented by the growing adoption of EHR systems. While many challenges impact performance measure development, endorsement, and implementation with EHR data in inpatient and outpatient settings, challenges related to eCQMs are unique since these are the primary settings where eCQMs have been adopted. The promise of eCQMs is to build on the foundation of structured data from EHR systems and other health IT systems to enable automated quality measurement. This was not possible in the days of primarily unstructured patient records.

While eCQMs are promising, the field faces several major challenges. First, EHR systems must support evolving eCQM standards and measure specifications. Second, eCQM standards have to align with actual EHR data collected during the documentation of care. Additionally, eCQMs often depend on data coming from multiple source systems, so interoperability of these systems is a major factor in successful reporting. Finally, eCQMs are meant to be automated from Clinical Quality Language (CQL)/Expression Logic Model (ELM) technical specifications. Currently, there is some variability in the extent that implementers can directly consume CQL/ELM to automatically calculate an eCQM.

Limited Number of Systems Support eCQM Capabilities

The Health IT Certification Program explicitly requires capabilities related to supporting eCQM reporting. Criterion 170.314 (c)(1) and criterion 170.315 (c)(1) require a health IT system to be able to capture and export clinical quality measure data. Criterion 170.314 (c)(2) and criterion 170.315 (c)(2) require the health IT system to import and calculate clinical quality measure data. Criterion 170.314 (c)(3) and criterion 170.315 (c)(3) require a health IT system to be able to report clinical quality measure data. The ONC Certified Health IT Product List (CHPL) indicates only 776 active certified health IT products that support all three eCQM capabilities.[4] Table 1 highlights the standards used by eCQMs required by existing ONC Certification criteria along with the adoption level according to the latest ONC Interoperability Standards Advisory (ISA):

Table 1. ONC Certification Criteria for eCQMs

Standard	Adoption Level
Health Quality Measures Format (HQMF) Release 2.1	4 out of 5
Clinical Quality Language (CQL) Release 1, Standard for Trial Use (STU) 1.3	3 out of 5
CQL Based HQMF Implementation Guide Release STU 4 based on HQMF R1	1 out of 5
Quality Reporting Document Architecture - Category III (QRDA III), STU Release 1	4 out of 5
Quality Reporting Document Architecture - Category III (QRDA III) STU Release 2.1	4 out of 5
Quality Reporting Document Architecture - Category I (QRDA I) Draft Standard for Trial Use (DSTU) Release 3.1 (US Realm)	4 out of 5
Quality Reporting Document Architecture - Category I (QRDA I) STU Release 4 (US Realm)	4 out of 5

The ONC ISA includes an adoption level that spans 1 (meaning low adoption) to 5 (meaning wide adoption). As eCQM standards are often updated, the adoption level for each eCQM standard varies as they are not yet widely adopted.

eCQM Standards Need to Align with EHR Data

EHR data requirements and measure criteria contained within an eCQM are not always aligned. This is not unique to eCQM standards: Many HL7 standards have data model alignment issues with structured EHR data. HL7 standards in general have faced issues aligning with actual structured EHR data and have presented an initial steep learning curve to implement. Furthermore, aligning data from EHR systems to be usable for EHR-based measures always requires some degree of data transformation. The need to address data alignment and ease of implementation issues, has contributed to the industry-wide push towards the development, maturation, and adoption of the Fast Healthcare Interoperability Resources (FHIR) specification.

FHIR is a framework and technical specification for healthcare data exchange.[5] A key goal of the FHIR specification is a strong focus on implementation. CMS is working with the HL7 FHIR community efforts

to bring FHIR's strong implementation focus to the eCQM space. The following are FHIR-based standards for implementing eCQMs:

- Quality Improvement-Core (QI-Core) is a FHIR implementation guide to describe the data element criteria similar to the Quality Data Model (QDM) specification.[6] As an FHIR Implementation Guide, QI-Core aims to benefit from the robust and improved mapping with structured EHR data that is being developed as part of the broader FHIR specification.
- FHIR Quality Measure Implementation Guide (QMIG) encapsulates the entire measure specification (analogous to HQMF). This is part of the large push towards development, maturation, and adoption of FHIR, which aims to better align with structured EHR data.
- Data Exchange for Quality Measures (DEQM) Implementation Guide is a specification used to represent a report containing the summary and individual results of a clinical quality measure.

One of the reasons that FHIR aims to be easier to implement is because implementation testing is a required part of the standards development process, and because FHIR makes use of existing secure web protocols, technologies, and formats for data exchange. Testing of FHIR is done via connectathons where vendors, standards developers, and other interested stakeholders meet in person and try to implement the FHIR specification.[7] The standards developer gets immediate feedback on modelling and implementation challenges that can then be addressed and incorporated early in the standards development process. Prior to the FHIR specification, most of the technical specifications used with eCQMs only received this level of implementation testing after the specification had been fully developed and published, which meant incorporating feedback took longer. Following are upcoming/recent FHIR connectathons that have tracks focusing on eCQM related use cases:

- CMS FHIR Connectathon 1[8]: This connectathon in January 2020 contained tracks for testing of the exchange and evaluation of data required for CMS quality reporting programs, including the Quality Payment Program, Hospital Inpatient Quality Program, and Web Interface. Specifically, this track involved testing the QI-Core, DEQM, and FHIR Quality Measure specifications[9].
- FHIR Connectathon 24[10]: This connectathon will be in May 2020 and will test quality measurement use cases under the clinical reasoning track.

In addition to the data modelling challenges, terminology-related challenges also impact how eCQM standards align with structured EHR data. Some terminology standards are Logical Observation Identifiers Names and Codes (LOINC) for laboratory test observations and Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT®) for laboratory test observation values, which have adoption levels of 3 out of 5 and 1 out of 5 respectively in the ONC ISA.[11] Vendors and providers that have not adopted these standards for these use cases may still capture laboratory data but need to map to these terminology standards in order to implement eCQMs. CMS, ONC, and the National Library of Medicine (NLM) offer the Value Set Authority Center (VSAC) as a repository of value sets used in eCQMs.

Implementation Challenges with EHR data in PAC settings

EHR data challenges in the post-acute care settings are affected by several major factors, including financial barriers, the quality goals of the Improving Medicare Post-Acute Care Transformation Act of 2014 (IMPACT Act), and ongoing standards and interoperability challenges. The PAC settings includes: skilled nursing facilities, home health agencies, inpatient rehabilitation facilities, and long-term care hospitals.

The ONC Health IT Certification Program (formerly Certified EHR Technology, or CEHRT) emerged as a result of the Health Information Technology for Economic and Clinical Health Act of 2009 (HITECH Act) and focused on incentivizing EHR system adoption in inpatient and outpatient settings. One barrier to EHR certification is the cost, which is significant for vendors and providers in PAC settings, particularly compared to inpatient and outpatient settings where providers and vendors benefited from the financial incentives of the EHR incentive programs. However, new payment models do shift incentives to align with quality improvement. The Patient Driven Payment Model (PDPM) changes the basis of payment towards paying for value and the Patient Driven Grouping Model (PDGM) changes the basis of payment to home health agencies from therapy services to patient and clinical characteristics.

The IMPACT Act establishes quality domains with corresponding measures and assessment that should be reported on across the PAC settings.[12] While the IMPACT Act established quality and resource use measures, the quality measures have yet to adopt using eCQMs. Table 2 shows the domains and measures:

Table 2. Domains and Measures of the IMPACT Act

IMPACT Act Domain	IMPACT Act Measure	PAC Setting Adopted
Skin Integrity and Changes in Skin Integrity	Percent of Residents or Patients with Pressure Ulcers that are New or Worsened (Short Stay) replaced with Changes in Skin Integrity Post-Acute Care: Pressure Ulcer/Injury	• Inpatient Rehabilitation Facilities (IRF) • Long Term Care Hospitals (LTCH) • Skilled Nursing Facilities (SNF) • Home Health Agencies (HH)

IMPACT Act Domain	IMPACT Act Measure	PAC Setting Adopted
Functional Status, Cognitive Function, and Changes in Function and Cognitive Function	• Application of Percent of LTCH Patients with an Admission and Discharge Functional Assessment and a Care Plan that Addresses Function • Application of Percent of LTCH Patients with an Admission and Discharge Functional Assessment and a Care Plan that Addresses Function • Application of Change in Self-Care Score for Medical Rehabilitation Patients • Application of Change in Mobility Score for Medical Rehabilitation Patients • Application of Change in Discharge Self-Care Score for Medical Rehabilitation Patients • Application of Change in Discharge Mobility Score for Medical Rehabilitation Patients	• IRF, LTCH, SNF, HH • LTCH • IRF, SNF • IRF, SNF • IRF, SNF • IRF, SNF
Medication Reconciliation	Drug Regimen Review	IRF, LTCH, SNF, HH
Incidence of Major Falls	Application of the Percent of Residents Experiencing One or More Falls with Major Injury (Long Stay)	IRF, LTCH, SNF, HH
Transfer of Health Information and Care Preferences when an Individual Transitions	Under Development	IRF, LTCH, SNF, HH
Resource Use Measures, including Total Estimated Medicare Spending Per Beneficiary	Medicare Spending Per Beneficiary	IRF, LTCH, SNF, HH
Discharge to Community	Discharge to Community	IRF, LTCH, SNF, HH
All-Condition Risk-Adjusted Potentially Preventable Hospital Readmissions Rates	Potentially Preventable 30-Day Post-Discharge Readmission	IRF, LTCH, SNF, HH

In addition to measures, the IMPACT Act has promoted the use of standardized assessment tools for measuring quality in each PAC setting. The following assessment tools are currently in use but are evolving to allow for better interoperability across PAC settings:

- Skilled nursing facilities use Minimum Data Set (MDS)
- Inpatient rehabilitation facilities use the Inpatient Rehabilitation Facility Patient Assessment Instrument (IRF-PAI)
- Home health agencies use Outcome and Assessment Information Set (OASIS)

Long-term care hospitals use the Long-Term Care Hospital Continuity Assessment Record & Evaluation (CARE) Data Set (LCDS) to create the Data Element Library (DEL) to standardize questions and responses used across the different assessment tools.[13] One goal is to reduce burden in completing assessment data by reusing existing structured EHR data when possible. CMS established the Post-Acute Care Interoperability Project (PACIO) to advance interoperability between PAC settings and others.[14] PACIO works with HL7 to leverage FHIR to support easier implementation of EHR data. The CMS FHIR Connectathon in January 2020 included a track that focused on testing and implementing a FHIR Implementation Guide[15] of the CMS DEL[16] to standardize questions and responses used across the different assessment tools[13]:

- CMS DEL Track focused on testing and implementing a FHIR Implementation Guide[15] of the CMS DEL.[16] A client application was able to successfully connect to the DEL FHIR API
- Functional/Cognitive Track focused on testing exchange of patient level functional status data and cognitive status data between disparate health IT systems. Two client applications were able to implement the current versions of the Functional Status Implementation Guide[1.7]

Unstructured EHR Data

EHR systems are primarily designed to support patient care and billing. Unstructured data are important to documenting patient care, and they are still common in EHR systems as they provide a means for clinicians to record qualitative information, provide a narrative, or document answers that can vary significantly between patients, e.g., patient goals in a care plan.[1] Additionally, some EHRs and health systems offer the ability to document narrative information (e.g., operative notes) as either structured or unstructured data and allow individual providers to choose their preferred approach. Some clinicians have noted that recording a clinical visit using only structured data can strip important and unique patient characteristics from the document—an issue that can be particularly problematic in certain care settings and specialties, e.g., behavioral health. Unstructured data can also reduce the burden of clinical documentation, since free-text notes can be faster to complete than notes with structured data. Many ongoing efforts strive to balance the clinical value of unstructured data with the quality and analytic value of structured data.

Limitations in the ability to document nuanced patient information can lead clinicians to rely on unstructured data even when structured data fields exist in the EHR.[18] One study that described the challenges of documenting patients' tobacco use found that the most frequent uses of free-text unstructured data were due to an insufficient ability to document relevant clinical information in the structured fields, including nuances that were not addressed in structured data fields (e.g., a patient who had repeatedly started and quit smoking cannot be easily captured in a single field for start/quit date). Additionally, data quality within the free text was impacted by acronyms, abbreviations, and misspellings, and in some cases, contradicted the information documented in the structured data fields. The authors suggested that both user training and natural language processing (NLP) could improve data quality and availability.[18] There is also a need for hospital EHR systems to include data as searchable data elements rather than free text to better implement eCQMs, especially in the wake of programs like Meaningful Use.[19]

In 2018, NQF convened a multistakeholder committee of clinical informatics and emergency medicine experts to develop a framework for advancing chief complaint-based quality measure development and implementation. The Committee found that NLP tools designed to capture and translate free-text chief complaint data from EHRs, while useful, require the ability to align data with one or more terms in a chief complaint ontology to mitigate data quality issues.[20] Numerous studies that used NLP to analyze unstructured data from patient charts at different health systems (including government facilities and academic medical centers) have demonstrated promising but varied results.[21–24] While other approaches to the analysis of unstructured data exist (such as domain specific language), literature reviews suggest that NLP is the most widely researched and promising approach within healthcare.

Chart abstraction is a useful step in designing automated processes to use unstructured data and may be a gold standard to assess certain characteristics of NLP. Because NLP can enable unstructured data to be used for eCQMs, a rigorous validation process must be utilized to ensure that the results of the eCQM are consistent with the unstructured data. Clinician inter-rater reliability is hindered by incomplete and missing data, low granularity, and ineffective chart review software that can make chart reviewers feel disconnected from the patient. User-centered design for the chart review software, indexed patient events, and increased data element granularity can all improve the chart review process and ultimately NLP.[25]

While unstructured data remain a challenging barrier to the automated use of clinical data for quality measurement, investments and improvements in Consolidated CDA (C-CDA) have led to decreases in unstructured clinical documentation. As one example, treatment plans were unstructured in previous C-CDA versions but are now structured. There is still a need, however, for common data quality terminology to establish a universal understanding of the strengths and limitations of EHR data for quality improvement.[26]

Data Quality Issues and NQF Endorsement

NQF defines eCQMs as measures that are specified using the industry accepted eCQM technical specifications: HQMF, QDM, CQL, and value sets vetted through the NLM's VSAC. Alternate forms of electronic measure specifications that do not use the accepted industry specifications are not considered eCQMs by NQF. NQF has endorsed nearly 540 healthcare performance measures with only 34 of these being eCQMs.[27] NQF is in the process of upgrading its data management system in ways that will allow for more robust analysis of those measures that are or are not endorsed (such as a count of how many submitted eCQMs did not pass the endorsement process), but because the existing data management system was implemented prior to the advent of eCQMs, these capabilities are not yet available.

NQF's Consensus Development Process was designed by multiple stakeholders and includes criteria that all submitted measures (including eCQMs) must pass in order to receive endorsement. If a submitted measure does not pass one of these criteria, review immediately ends without the remaining criteria being assessed. For example, if a measure does not pass the importance to measure and report criterion, the Standing Committee does not review it for scientific acceptability. NQF has proposed a process that would create opportunities for developers of non-passing measures (again, including

eCQMs) to receive additional information and/or technical assistance, but resources are not currently available for this extended level of support. In light of the legacy data management system and the current endorsement process, the information in this section of the environmental scan is based on stakeholder experience with submitting eCQMs to NQF for endorsement consideration, and NQF staff experience with facilitating the process.

The lower volume of eCQMs in NQF's portfolio is thought to be, in part, due to the lack of the requisite testing needed for endorsement. To be considered for NQF endorsement, all eCQMs must be tested empirically using the HQMF specifications and, as of 2019, data element validation is required. For eCQMs based solely on structured data fields, reliability testing is not required if data element validation is demonstrated. If data element testing is not possible, justification is required and must be approved by the Standing Committee. Reliance on data from structured data fields is expected; otherwise, unstructured data must be shown to be both reliable and valid.

Measure developers have expressed several challenges with meeting the NQF eCQM scientific acceptability criterion. Acquiring readily available EHR data to support the statistical rigor or sample sizes required for scientific acceptability is challenging. The minimum requirement is testing in EHR systems from more than one EHR vendor, and it is highly desirable that measures are tested in systems from multiple vendors. Developers have faced several challenges with this. In order for measure developers to fully participate in eCQM testing, a clinical practice or facility test site (or their EHR vendor) must implement the measure in advance of formal inclusion in a CMS federal program. This can be challenging financially, operationally, and logistically for the sites, as typical honorarium-type compensation offsets only a fraction of the actual cost.

When a measure is ready to be submitted for endorsement consideration, it can be challenging to secure an acceptable number of EHR systems within healthcare organizations that are willing and able to participate in testing scientific acceptability. Additionally, recruitment for testing has been difficult, particularly because sites do not always use validated tools and/or standardized methods of EHR reporting for screening or interventions as specified in a particular measure. Identifying test sites that are currently collecting all required data elements is also difficult because some data elements may not score well on the NQF Feasibility Scorecard, which defines workflow as the extent to which capturing data elements impacts the typical workflow for that user. A score of 1 is assigned if the data element is routinely collected during clinical care and requires no, or limited, additional data entry from a clinician or other provider, and no EHR interface changes. A score of 0 is assigned if the data element is not routinely collected during clinical care and additional time and effort are required to collect this data element without perceived benefit to care. For example, various test sites have reported that they do not routinely capture medical exceptions and limited life expectancy data.

Stakeholders have also expressed concern about endorsement criteria that are occasionally unclear or challenging to meet. One example is whether it's acceptable to test eCQM implementation using EHR data transmitted from multiple CEHRT vendor platforms and sites to a centralized or normalized warehouse where the actual measure calculation and outcomes are performed. This would be done instead of using individual facility/practice CEHRT data where the measure calculations are done locally

by the individual CEHRT EHR or quality reporting engine. The current NQF criteria states that if a developer is testing an eCQM using any type of normalized EHR clinical data (e.g. from multiple EHR sources), NQF requires, at a minimum, supporting information of what schemas are included in the normalized data set and how they are calculated by the measure logic (i.e., what fields have been normalized and how, including any considerations of how this may affect the measure).

Recognizing that not all Standing Committee members may be well-versed in the technical aspects, each submitted eCQM undergoes a technical review by NQF staff before going to the Standing Committee for evaluation. The purpose of this technical review is to reduce the burden on Standing Committee members who do not have an in-depth level of expertise with eCQM measure specifications. The staff review includes an interpretation of how the eCQM may meet the endorsement criteria and is intended to guide the Standing Committee during its evaluation. Some stakeholders have expressed that there has been a lack of consistency among Standing Committees in the application of the measure endorsement criteria. However, it should be noted that similar inconsistencies have been identified during the evaluation of measures that use other data sources, and while human judgment always carries a risk of subjectivity, this issue is not inclusive of eCQMs.

An example of an eCQM that did not pass the scientific acceptability criteria includes a measure with empirical validity testing done at the data element and performance measure score level. The measure failed the reliability criterion because, at a systemic level, there was poor agreement between the time a patient sees a provider and what is documented in the chart. In another unsuccessful example, the developer attempted to demonstrate reliability by performing data element testing at one hospital site. The testing involved implementation of the eCQM to compute scores automatically and manual chart review of the same patients by a trained chart abstracter; inter-rater reliability was then assessed. Agreement was 100 percent for all critical data elements, and 100 percent for overall clinical performance of the measure. However, because the developer presented reliability results at the data element level in only a single facility, the measure did not pass on reliability. For another eCQM, there were several concerns about how the evidence aligned with the specifications, and stakeholders did not find the measure as specified to be a valid indicator of quality. As with measures using all data sources, the Committee must determine that the measure specifications are consistent with the evidence in order to meet the validity sub criterion under scientific acceptability, which this eCQM did not pass.

As with virtually everything related to healthcare quality, improvement in the eCQM development, endorsement, and implementation process is iterative and ongoing. On occasion, issues have been identified with eCQMs that made it through the endorsement process successfully. One article characterized completeness, computability, and accuracy for five NQF-endorsed eCQMs, but found there were inherent barriers with incomplete measure specifications, data availability, and variations in data element specification. In fact, one measure specification could not be computed and the specification guidance for one data element differed significantly from its correlate in the EHR. These factors led to inaccurate eCQM results.[28]

An additional requirement for the endorsement of eCQMs includes a feasibility assessment (i.e., scorecard), as described in the eMeasure Feasibility Assessment Report.[29] The feasibility assessment

must address the data elements and measure logic and demonstrate that the eCQM can be implemented or that feasibility concerns can be adequately addressed. Domains to be addressed in the assessment include: data availability, data accuracy, data standards and workflow. Although feasibility is not currently a must-pass criterion for NQF endorsement, feasibility issues identified in the assessment can impact criteria that are must-pass. For example, if a data element has feasibility issues identified in the accuracy domain, the Standing Committee should take this into account when evaluating the validity testing for that measure. Additionally, lack of feasibility is likely to impede measure adoption, reducing the potential impact of eCQMs on burden reduction.

Promising and Best Practices in EHR Data Quality and eCQMs

While there are a variety of reasons why eCQMs fail during endorsement, there are also several studies that highlight promising and best practices for the development, endorsement, and implementation of eCQMs. Additionally, given the relatively small number of endorsed eCQMs, there are not an extensive number of studies, but lessons can be learned from related articles that look at the intersection between EHR data quality and healthcare performance measures.

One article described a validation strategy that leveraged the strengths of a stakeholder workgroup of EHR experts and representatives to guide the development and testing process for two oral health eCQMs developed by the Dental Quality Alliance. This level of stakeholder engagement helped identify otherwise-unanticipated threats to feasibility, reliability, and validity early in the process. For example, errors were identified in the measure logic evident in initial results generated at a test site.[30]

Welch, et al. described an approach to sepsis by a High Value Healthcare Collaborative (HVHC), whose efforts exemplified the critical nature of data checking early in the healthcare intervention process. The HVHC successfully utilized a single data coordinating center, frequent communication, multiple quality checks, and early prototype analysis. By doing so, members participating in the study could resubmit their data instead of having their submission excluded because of severe errors. Data checking also assisted the authors in discovering intensive care unit stays were defined differently for members and Medicare, a potential pitfall that was remedied in part due to their data checking strategy. The lessons learned by this multi-site, two-year project can be applied to other organizations measuring outcomes using bundled measures. The authors recommended additional data cleaning and evaluation research.[31]

To validate transient ischemic attack (TIA) and minor ischemic stroke eCQMs, Bravata et al. successfully compared eCQMs constructed using EHR data to the same quality measures developed using chart review data. The developers found that most of the mismatches came from a small number of error types. By focusing more closely on these error types (disposition categories, contraindications, device orders, and bar coded medication administration) and subsequently standardizing the data elements, developers improved the accuracy of the eCQMs.[19]

To assist with quality improvement in cardiac catheterization laboratories, the Veterans Affairs (VA) health system developed an internal EHR program called “VA Clinical Assessment, Reporting, and Tracking System for Cath Labs” (CART). The program was characterized by standard definitions as well as program screens and menus. By having providers input data at point of care, transcription and recall

errors are minimized. Auditing, feedback tools, required element completion, and user training were other methods used by the VA for successful implementation.[32]

A few articles described NLP programs that appear to be reliable, particularly for well-defined variables.[33] One article described efforts to map data to current terminology standards, such as LOINC and the International Classification for Nursing Practice (ICNP), including a manual abstraction and comparison approach for dealing with identified discrepancies.[34] Another article described the importance of automated tooling programs that detect data quality issues and the role of such programs in improving standards implementation and adoption as well as identifying and resolving barriers to clinical document exchange.[26]

One study determined an acceptable level of data currency (i.e. timeliness) could be obtained if a completely electronic system was used instead of using paper-based or mixed documentation sources. High completeness was noted amongst data elements where EHRs were used for vital signs, which related vital sign registration to documented time of arrival. To improve data quality and optimize future development of eCQMs, organizations should consider using EHRs for the entire documentation process.[35]

During the development and implementation of two pediatric eCQMs related to attention deficit hyperactivity disorder (ADHD) and adolescent preventive health, one study's authors concluded that the successful implementation could be credited to streamlined integration with clinical care workflows and overcoming challenges with the data structure, data capturing process and inherent measure specification requirements.[27]

An analysis of the successful implementation of stroke eCQMs within the VA health system revealed that although there were some concerns with accuracy, continual improvements to the VA EHR and use of structured query language (SQL) were instrumental. The authors recommend that future efforts should consider standardizing data elements.[36]

The above studies show that there are multiple approaches to ensuring EHR data quality in ways that support the development, endorsement, and implementation of eCQMs. Specific discussions of topics like data currency and accuracy highlight the need for a standardized framework to assess EHR data quality.

Frameworks for Assessing EHR Data Quality

The literature review identified a variety of proposed frameworks for assessing the data quality in EHRs, in the context of both applications for clinical research and the development of eCQMs.

Although there are several frameworks identified in the literature, a systematic review of these in 2013 by Weiskopf et al. suggests that these frameworks are inconsistent, and few researchers bypassed intuition and ad hoc methods in favor of generalizable approaches that could lead to a standardized methodology of data quality. Nevertheless, the authors synthesized the frameworks in order to identify and define EHR data quality constructs that appeared consistently across frameworks. Building on that work, in 2017, Weiskopf et al. conducted an extensive series of semi-structured interviews in order to

elucidate additional data quality constructs that were meaningful and distinct from those identified in the literature review.[37] The constructs identified were:

- Completeness: A truth about a patient was present in the EHR, i.e. data availability
- Correctness: The information contained in the EHR was true
- Concordance: There was agreement or compatibility between data elements
- Plausibility: The data were in agreement with general medical knowledge, such as biologically possible ranges
- Currency: The data were recorded in a reasonable period of time, i.e. the timeliness or recency of the data
- Granularity: A data value was neither too specific nor too broad
- Fragmentation: A concept was recorded in only one place in the record
- Signal-to-noise: Information of interest could be distinguished from irrelevant data in the record
- Structuredness: Data were recorded in a format that enables reliable extraction

It is notable that these constructs intersect with the current NQF eCQM Feasibility Scorecard in a few key areas (e.g., availability and accuracy), but there is not complete alignment. This is perhaps indicative of the opportunity and need for a standardized set of constructs.[38]

Two additional systematic literature reviews of EHR data quality constructs and definitions advanced many concepts that were consistent with the work of Weiskopf et al. In the 2018 study, *Data Quality in Electronic Health Records Research: Quality Domains and Assessment Methods*,[39] Feder identified accuracy, completeness, consistency, credibility, and timeliness as constructs, each of these with a direct analogy to the Weiskopf concepts. Meanwhile, another study identified several constructs with some overlap to the Weiskopf concepts, including[40]:

- Uniformity: Measurements across time and data sources all have the same units, duration, and/or coding system
- Time patterns: There are no unexpected changes over time
- Linkage: Entities occurring in multiple data tables can be linked
- Identity: There are no duplicates
- Event attributes: all attributes relevant to an event are present
- Consistency of hospitals within data warehouse: There are no unexplained differences between hospitals

Meta-analyses identified a variety of approaches to mitigate EHR data quality issues, generally in support of clinical research as opposed to performance measures.[37,40] These approaches included verifying a data element by comparing the value against a known quantity that could be assumed to be correct or a "gold standard." Other approaches relied on clinical knowledge, identifying issues with data quality when data element results fell outside expected clinical norms.

In several cases, validation strategies consisted of buttressing reliability and validity of an individual EHR data element by combining these data with others, either internal to the EHR or from an external source. For an example of the former approach, one group attempted to improve diagnosis

documentation for patients with multiple chronic conditions by combining data from the problem lists, medical history, and medication lists. This improved the EHR diagnosis extraction from roughly 70 percent correctness as compared to equivalent performance to a gold standard.[41] Other groups leveraged data sources external to the EHR as an alternative to a gold standard, such as an annual blood bank report[40] or the Social Security Death Index.[42]

Guidance from Standard-Setting Bodies

Other articles in the environmental scan emphasized the need and importance of regulatory bodies and accrediting organizations in setting standards for the quality of EHR data used for measurement.[43] Support for developing and subsequent testing for electronically based pediatric quality measures is included within the AHRQ Pediatric Quality Measure Program,[44] part of the Children's Health Insurance Program Reauthorization Act (CHIPRA) of 2009. In addition, the legislation emphasized developing a "model children's EHR format" and created a demonstration grant program. The article described multiple federal efforts to improve usage of health information.[27]

Table 3. Key Guidance from Standard Setting Bodies

Legislation	Key Quality Areas
American Recovery and Investment Act of 2009 (ARRA)	Additional support for EHR research[45]
Children's Health Insurance and Program Reauthorization Act of 2009 (CHIPRA)	Set minimum standards for EHR developers, created new e-measures and evaluated state-level endeavors in using health IT to improve pediatric care quality[46]
Health Information Technology for Economic and Clinical Health Act of 2009 (HITECH)	Financial incentives for providers to adopt and meaningfully use EHR[47]
Improving Medicare Post-Acute Care Transformation Act of 2014 (IMPACT)	Standardized post-acute care data to improve outcomes[48]
Patient Protection and Affordable Care Act of 2010 (PPACA)	Incorporated existing incentive programs into value-based purchasing program with payments linked to certain EHR-related quality measures[49]

Next Steps

The TEP will use the results of the environmental scan to spur discussion and identification of consensus recommendations for promoting data quality and the potential role for standards-setting organizations. The TEP also will use the results of the scan when applying these recommendations to its discussions assessing NQF's eCQM evaluation criteria within the Consensus Development Process (CDP).

Glossary

TERM	DEFINITION
Bonnie	Bonnie is a tool for testing electronic clinical quality measures (eCQMs). This tool is designed for use by measure developers as part of their development process and validates that the eCQM logic matches the measure's intent. Bonnie uses patient scenarios to represent each logic component of the measure specification such as the initial patient population (IPP), denominator, numerator, exclusions, etc. Health IT developers and implementers may also use the tool to evaluate measure implementation into their systems. Measure developers use both Bonnie and the Measure Authoring Tool (MAT) in concert to promote test driven development.[50]
Clinical Decision Support (CDS)	CDS is a process for enhancing health-related decisions and actions with pertinent, organized clinical knowledge and patient information to improve health and healthcare delivery. The information delivered can include general clinical knowledge and guidance, intelligently processed patient data, or a mixture of both. Information delivery formats can include data and order entry facilitators, filtered data displays, reference information, alerts, and others.[50]
Clinical Document Architecture (CDA)	The HL7 Version 3 Clinical Document Architecture (CDA®) is an HL7 standard in XML-based document markup standard that specifies the structure and semantics of "clinical documents" for the purpose of exchange between healthcare providers and patients. It defines a clinical document as having the following six characteristics: persistence, stewardship, potential for authentication, context, wholeness, and human readability. A CDA can contain any type of clinical content—typical CDA documents would be a Discharge Summary, Imaging Report, Admission & Physical, Pathology Report, etc. The most popular use is for inter-enterprise information exchange, such as is envisioned for a US Health Information Exchange (HIE).[50]
Clinical Quality Language (CQL)	CQL is a high-level, domain-specific language focused on clinical quality and targeted at measure and decision support artifact authors.[51]
Clinical quality measures (CQM)	Clinical quality measures are tools that help measure and monitor the quality of healthcare and the contribution of healthcare services towards improved health outcomes. In the past, quality measures primarily used data that came from claims, but as technology has improved and become more prominent in the healthcare setting, many quality measures now use data that comes from a provider's electronic health record (EHR). These eCQMs use EHR data to measure health outcomes, clinical processes, patient safety, efficient use of healthcare resources, care coordination, patient engagement, and population and public health improvement. [50]
Completeness	Completeness is the availability and accessibility of expected entries in the EHR.[35]

TERM	DEFINITION
Computability	Computability is the extent to which an eCQM specification algorithm can be translated to programmable logic constructs and the availability of EHR data elements to implement the eCQM specified QDM data criteria.[28]
Current Procedural Terminology (CPT)	This code set is maintained by the American Medical Association. The CPT code set describes medical, surgical, and diagnostic services and is designed to communicate uniform information about medical services and procedures among physicians, coders, patients, accreditation organizations, and payers for administrative, financial, and analytical purposes. CPT coding is similar to ICD-9 and ICD-10 coding, except that it identifies the services rendered rather than the diagnosis on the claim. (ICD code sets also contain procedure codes, but these are only used in the inpatient setting.) CPT is currently identified by the Centers for Medicare and Medicaid Services as Level 1 of the Healthcare Common Procedure Coding System. [50]
Cypress	Cypress is an open source certification testing tool for evaluating the accuracy of clinical quality measure calculations in EHR systems and EHR modules. Cypress enables testing of an EHR's ability to accurately calculate eCQMs. Cypress serves as the official eCQM testing tool for the 2014 EHR Certification program by the Office of the National Coordinator for Health IT (ONC). [50]
Data Element Feasibility	Data Element Feasibility is the likelihood that data elements are available and a significant number of organizations can capture and access the data element in a consistent manner.[50]
CMS Data Element Library (DEL)	The CMS Data Element Library is the centralized resource for CMS assessment instrument data elements and their associated health information technology (IT) standards.[13]
Data Exchange	Data Exchange is the process of sending and receiving data in such a manner that the information content or meaning assigned to the data is not altered during the transmission.[50]

TERM	DEFINITION
Data Exchange for Quality Measures (DEQM)	The Data Exchange for Quality Measures Implementation Guide provides a framework that defines conformance profiles and guidance to enable the exchange of quality information and quality measure reporting. The DEQM expects to use quality measures specified in accordance with the Quality Measure Implementation Guide and QI-Core.[50]
Denominator	The denominator can be the same as the initial patient population or a subset of the initial patient population, to further constrain the population for the purpose of the eMeasure. Different measures within a set may have the same initial patient population but different denominators. Continuous Variable measures do not have a denominator, but instead define a Measure Population. For proportion or ratio measures, the verbiage "Equals Initial Patient Population" with no additional criteria indicates the denominator is identical to the initial patient population.[50]
Electronic Clinical Quality Measure (eCQM)	Electronic clinical quality measures are eMeasures specified for use in the Medicare and Medicaid EHR Incentive Programs. Eligible professionals, eligible hospitals, and critical access hospitals (CAHs) are required to submit CQM data from certified EHR technology to help measure and track the quality of healthcare services provided within the healthcare system. These measures use data associated with providers' ability to deliver high-quality care or relate to long term goals for quality healthcare.[50]
Electronic Health Record (EHR)	An electronic health record is a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports. The EHR automates and streamlines the clinician's workflow. The EHR has the ability to generate a complete record of a clinical patient encounter, as well as supporting other care-related activities directly or indirectly via interface, including evidence-based decision support, quality management, and outcomes reporting.[50]
Expression Logic Model (ELM)	An ELM is a machine-readable canonical representation of CQL targeted at implementations and designed to enable sharing of clinical knowledge.[51]
Electronic Medical Record (EMR)	An EMR is a digital version of a paper chart that contains all of a patient's medical history from one practice. It is mostly used by providers for diagnosis and treatment. The difference between an EMR and an EHR is that an EHR is designed to share information with other healthcare providers, such as laboratories and specialists. The National Alliance for Health Information Technology stated that EHR data "can be created, managed, and consulted by authorized clinicians and staff across more than one healthcare organization."[50]

TERM	DEFINITION
Fast Healthcare Interoperability Resources (FHIR)	Fast Healthcare Interoperability Resources is a next-generation standards framework created by HL7 (hl7.org/fhir). FHIR combines the best features of HL7's Version 2, Version 3, and CDA® product lines, while leveraging the latest web standards and applying a tight focus on implementability. FHIR solutions are built from a set of modular components called "resources." These resources can easily be assembled into working systems that solve real world clinical and administrative problems at a fraction of the price of existing alternatives. FHIR is suitable for use in a wide variety of contexts, including mobile phone apps, cloud communications, EHR-based data sharing, server communication in large institutional healthcare providers, and much more. [50]
FHIR Quality Measure Implementation Guide (QMIG)	The FHIR Quality Measure Implementation Guide defines conformance profiles and guidance focused on the specification of quality measures using the FHIR Measure and Library resources. The QMIG does not standardize the content of any particular measure, rather it defines the standard approach to the representation of that content so that quality measure specifiers can define and share standardized FHIR-based eCQMs.[52]
Health Information Exchange (HIE)	HIE is a term used to describe both the sharing of health information electronically among two or more entities and also an organization which provides services that enable the sharing electronically of health information.[50]
Health Information Technology for Economic and Clinical Health (HITECH) Act	The HITECH Act provides HHS with the authority to establish programs to improve healthcare quality, safety, and efficiency through the promotion of health IT, including EHRs and private and secure electronic health information exchange.[50]
Health Insurance Portability and Accountability Act (HIPAA)	HIPAA provides federal protections for personal health information held by covered entities and gives patients an array of rights with respect to that information.[50]
Health IT Policy Committee (HITPC)	HITPC is a Federal Advisory Committee that coordinates industry and provider input regarding the Medicare and Medicaid Incentive Programs as well as in consideration of current program data for the Medicare and Medicaid EHR Incentive Programs.[50]

TERM	DEFINITION
Healthcare Common Procedure Coding System (HCPCS)	HCPCS is a set of healthcare procedure codes based on the American Medical Association's Current Procedural Terminology (CPT). HCPCS was established in 1978 to provide a standardized coding system for describing the specific items and services provided in the delivery of healthcare necessary for Medicare, Medicaid, and other health insurance programs to ensure that insurance claims are processed in an orderly and consistent manner. With the implementation of the Health Insurance Portability and Accountability Act of 1996 (HIPAA), use of the HCPCS for transactions involving healthcare information became mandatory. HCPCS is divided into two principal subsystems, referred to as Level I and Level II. Level I is comprised of the CPT-4 to identify medical services and procedures furnished by physicians and other healthcare professionals. The Level II HCPCS is a standardized coding system that is used primarily to identify products, supplies, and services not included in the CPT-4 codes. It is maintained and distributed by CMS.[50]
Healthcare Quality Measures Format (HQMF)	HQMF is a Health Level 7 (HL7) international standard that serves as a wrapper into which a health quality measure using the QDM can be placed. The HQMF serves as a means to share and distribute a clinical quality measure as an electronic document.[50]
Human readable	Each eCQM exported from the Measure Authoring Tool (MAT) includes the measure specifications in an HTML human readable format so that the user can understand both how the elements are defined and the underlying logic used to calculate the measure.[50]
International Classification of Diseases (ICD)	The ICD terminology is maintained by the World Health Organization, the directing and coordinating authority for health within the United Nations System. The ICD is designed as a healthcare classification system, providing a system of diagnostic codes for classifying diseases, including nuanced classifications of a wide variety of signs, symptoms, abnormal findings, complaints, social circumstances, and external causes of injury or disease. Diagnosis codes are key for determining coverage and are used in treatment decisions. From plan design to statistical tracking of disease, these codes are a crucial part of the way health plans—including State Medicaid agencies—run their programs. Current health plan systems and healthcare providers are required by HIPAA to use a standard code set to indicate diagnoses and procedures on transactions.[50]
Interoperability	The ability of a system to exchange electronic health information with and use electronic health information from other systems without special effort on the part of the user.[53]

TERM	DEFINITION
Initial Patient Population (IPP)	The initial patient population refers to all patients to be evaluated by a specific performance eMeasure. These patients share a common set of specified characteristics within a specific measurement set to which a given measure belongs. This initial patient population is present regardless of the measure scoring type; i.e., proportion, ratio, and continuous variable measures all have an initial patient population section. Details often include information based upon specific age groups, diagnoses, diagnostic and procedure codes, and enrollment periods.[50]
Logical Observation Identifiers Names and Codes (LOINC)	LOINC is a database and universal standard for identifying medical laboratory observations. It was developed in 1994 and is maintained by the Regenstrief Institute, a US non-profit medical research organization. LOINC was created in response to the demand for an electronic database for clinical care and management and is publicly available at no cost.[50]
Medicare and Medicaid EHR Incentive Programs	The American Recovery and Reinvestment Act of 2009 authorized CMS to provide incentive payments to eligible professionals (EPs) and hospitals who adopt, implement, upgrade, or demonstrate meaningful use of certified EHR technology—commonly referred to as "Meaningful Use"[50]and currently known as the Promoting Interoperability Programs.
Measure Scoring	Measure scoring indicates how a calculation is performed for the eMeasure (e.g., proportion, continuous variable, and ratio).[50]
Measure Type	Measure type indicates whether the eMeasure is used to examine a process or an outcome over time (e.g., Structure, Process, and Outcome).[50]
Measurement Period	Measure period is the time period for which the eMeasure applies.[50]
Measure Population	Measure population is used only in continuous variable eMeasures. It is a narrative description of the eMeasure population. (e.g., all patients seen in the Emergency Department during the measurement period).[50]
Numerator	Numerators are used in proportion and ratio eMeasures. In proportion measures the numerator criteria are the processes or outcomes expected for each patient, procedure, or other unit of measurement defined in the denominator. In ratio measures, the numerator is related, but not directly derived from the denominator (e.g., a numerator listing the number of central line blood stream infections and a denominator indicating the days per thousand of central line usage in a specific time period).[50]

TERM	DEFINITION
Promoting Interoperability Programs	The Promoting Interoperability Programs (previously known as The Medicare and Medicaid EHR Incentive Programs) provides incentive payments to eligible professionals and eligible hospitals as they demonstrate adoption, implementation, upgrading, or meaningful use of certified EHR technology. These interoperability programs are designed to support providers in this period of health IT transition and instill the use of EHRs in meaningful ways to help our nation to improve the quality, safety, and efficiency of patient healthcare.[54]
Quality Data Model (QDM)	A QDM element is a discrete unit of information used in quality measurement to describe part of the clinical care process, including a clinical entity and its context of use. It can include criteria for any relevant metadata about a clinical or administrative concept relevant to quality measurement. A QDM element provides an unambiguous definition and enables consistent capture and use of data for quality measurement. It may be defined for any given measure and reused when the same information is required for another measure. Reuse encourages standardization of quality measures and reduces the generation of additional software requirements for every new measure.[50]
Quality Improvement Core Implementation Guide (QI-Core)	The Quality Improvement Core Implementation Guide defines a set of FHIR profiles with extensions and bindings needed to create interoperable, quality-focused applications. Importantly, the scope of QI-Core includes both quality measurement and decision support to ensure that knowledge expressed can be shared across both domains. QI-Core is derived from US-Core, meaning that where possible, QI-Core profiles are based on US-Core to ensure alignment with and support for quality improvement data within healthcare systems in the US Realm.[52]
Quality Reporting Document Architecture (QRDA)	The Health Level Seven International (HL7) Quality Reporting Document Architecture is a standard document format for the exchange of eCQM data. QRDA reports: • Contain data extracted from EHRs and other health information technology systems. • Can be used to exchange eCQM data between systems. • Are the data submission standards for a variety of quality measurement and reporting initiatives. • Were adopted by the ONC as the standard to support both QRDA Category I (individual patient) and QRDA Category III (provider's aggregate) data submission approaches for Stage 2 of Meaningful Use.[50]

TERM	DEFINITION
RxNorm	RxNorm is a nonproprietary drug vocabulary maintained and distributed by the National Library of Medicine. It has been identified as the vocabulary of choice to be incorporated into government systems as they are updated. RxNorm provides normalized names for clinical drugs and links its names to many of the drug vocabularies commonly used in pharmacy management and drug interaction software.[50]
State Health Information Exchange (HIE)	The state HIE program promotes innovative approaches to the secure exchange of health information within and across states. It also works to ensure that healthcare providers and hospitals meet national standards and Meaningful Use requirements. The Office of the National Coordinator for Health Information Technology (ONC) funds the State Health Information Exchange (HIE) Cooperative Agreement Program.[50]
Systematized Nomenclature of Medicine-Clinical Terms (SNOMED-CT)	SNOMED-CT is a comprehensive clinical terminology, owned, maintained, and distributed by the International Health Terminology Standards Development Organisation (IHTSDO).[50]
Taxonomy	Taxonomy is a standard vocabulary or other classification system that can be used to define a QDM element's category. For the purpose of the QDM, taxonomy is synonymous with a code system (a collection of codes with associated designations and meanings). Specific taxonomies are used in applying the QDM to quality measures based on the recommendations of the HIT Standards Committee of the ONC and established certification rules for Meaningful Use.[50]
Value Set	Previously referred to as code list, a value set is a set of values that contain specific codes derived from a particular taxonomy. Value sets are used to define an instance of a category used in a QDM element. A parent value set may also contain child (or nested) value sets that define the same category. The approach is consistent with the HL7 definition for a value set as "a uniquely identifiable set of valid concept representations, where any concept representation can be tested to determine whether or not it is a member of the value set…A sub-value set is a sub-set of a 'parent' value set…When a value set entry references another value set, the child value set is referred to as a nested value set. There is no preset limit to the level of nesting allowed within value sets. Value sets cannot contain themselves, or any of their ancestors (i.e. they cannot be defined recursively)." With respect to value sets, a value is a specific code defined by a given taxonomy. Values are included in value sets. In the context of QDM elements, some categories (e.g., laboratory test) have an attribute of "result." A result may be expressed as a value (numeric or alphanumeric).[50]

TERM	DEFINITION
Value Set Authority Center (VSAC)	A service provided National Library of Medicine (NLM), in collaboration with the ONC and CMS, the VSAC provides downloadable access to all official versions of vocabulary value sets contained in Clinical Quality Measures (CQMs) used in federal programs. Each value set consists of the numerical values (codes) and human-readable names (terms), drawn from standard vocabularies such as SNOMED CT®, RxNorm, LOINC, and ICD-10-CM, which are used to define clinical concepts used in CQMs (e.g., patients with diabetes, clinical visit). The content of the VSAC will gradually expand to incorporate value sets for other use cases, as well as for new measures and updates to existing measures.[50]
XML (Extensible Markup Language)	This is a computer readable format which enables the automated creation of queries against an EHR or other operational data store for quality reporting. XML provides a basic syntax that can be used to share information among different computers, applications, and organizations without needing to pass through many layers of conversion.[50]

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Appendix A: TEP and NQF Staff

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Appendix B: Environmental Scan Methodology

This environmental scan was conducted to understand how EHR data can be used to address quality issues and the impact these issues have on the scientific acceptability, feasibility, and use and usability of clinical quality measures.

Several research questions helped guide the scan. These included:

- How do measure developers currently assess EHR data quality prior to developing, testing, and implementing eCQMs?
- What are the approaches currently used to mitigate data quality challenges? How do the approaches vary based on the specific data quality issue (i.e., validity, lack of structured data)?
- What data are needed to support development and testing of eCQMs?
- What are the structural and organizational attributes of institutions that have successfully implemented eCQMs supported by EHRs with validated data quality?
- How have data quality issues impeded endorsement of eCQMs submitted to NQF's Consensus Development Process?
- What guidance have standard-setting bodies already promulgated to help mitigate EHR data quality issues?

NQF relied on PubMed, Google Scholar, previous NQF reports, and additional relevant sources from HL7, CMS, and ONC to characterize the causes, nature and extent of EHR data quality issues. NQF searched these databases using combinations and variations of the example search terms shown in Table B1.

Table B1. Literature Search Parameters

Included	Excluded
• Published on or after January 1, 2014 • Relevant MeSH Terms: EHR data quality, Reliability, Validity, eMeasure Data Quality, eCQM Data Quality, Electronic Clinical Quality Measure Data Quality, Certified EHR Technology, Certified EHR Data Quality • Contains the strings: "EHR" AND (("data accuracy" OR ("data" AND "accuracy") OR "data accuracy" OR ("data" AND "quality") OR "data quality") AND Feasibility) • Contains the strings: "Electronic Health Record" AND "Data Quality"AND "Structured Fields" • Contains the strings: "ehr" AND ("data accuracy" OR ("data" AND "accuracy") OR "data accuracy" OR ("data" AND "quality") OR "data quality") AND "reliability") • Contains the strings: ("data accuracy" OR ("data" AND "accuracy") OR "data accuracy" OR ("data" AND "quality") OR "data quality") AND Validity AND ("electronic health records" OR ("electronic" AND "health" AND "records") OR "electronic health records" OR ("electronic" AND "health" AND "record") OR "electronic health record") • Contains the strings: ("data accuracy" OR ("data" AND "accuracy") OR "data accuracy" OR ("data" AND "quality") OR "data quality") AND ("reliability") AND ("electronic health records" OR ("electronic" AND "health" AND "records") OR "electronic health records" OR ("electronic" AND "health" AND "record") OR "electronic health record")	• For the initial literature searches, we excluded articles published before 2014. However, some legacy articles published before 2014 describing EHR attributes are included • Not available in English

NQF identified grey literature and other published literature through internet searches of relevant organizations/efforts. These included:

- HL7 International: https://www.hl7.org
- Centers for Medicare & Medicaid Services (CMS): https://www.cms.gov

In addition, TEP members identified additional articles, reports, and websites.

NQF staff reviewed previous work by NQF relevant to the objectives of this scan.

The senior project managers and consultant for the project identified the search terms and parameters used for the scan. Staff members shared responsibility for conducting the searches for published articles and grey literature.