IMPROVING MAMMOGRAM RESULT DATA QUALITY IN AN ELECTRONIC HEALTH RECORD WITH A BREAST IMAGING-RESULTS AND DATA SYSTEM-ELECTRONIC HEALTH RECORD INTERFACE

By

Jorge J. Scheirer, MD, FACP

A CAPSTONE PROJECT

Presented to the Department of Medical Informatics and Clinical Epidemiology
and the Oregon Health & Science University School of Medicine
in partial fulfillment of
the requirements for the degree of
Master of Science

February 2012

TABLE OF CONTENTS

School of Medicine

Oregon Health & Science University

Certificate of Approval

This is to certify that the Master's Capstone Project of

Jorge J. Scheirer

"Improving Mammogram Result Data Quality in an Electronic Health Record with a Breast Imaging-Result and Data System-Electronic Health Record Interface"

Has been approved

_____

Capstone Advisor

Acknowledgements

Richard Alweis, MD, FACP assisted in refining the mammogram result terms, in the review of mammogram results that had not interfaced with the EHR and gave feedback on the manuscript. Elizabeth Clay and Joseph Liu reviewed EHR mammogram field entries and collected the raw data for the project.

Thanks to my wife, Tracy and children Elizabeth, Victoria, William, and Andrew for all your love, support, and understanding while I spent many hours at the computer going through this process.

Abstract

Objective: To assess the impact of a Breast Imaging Results And Data System (BI-RADS) and electronic health record (EHR) interface on the quality of mammogram results data stored in an EHR database.

Setting: Ambulatory internal medicine faculty practice affiliated with a large academic community hospital.

Methods: The quality of mammogram result entries in an EHR for women between 40-65 years of age during a fifteen-month period prior to the creation of a BI-RADS-EHR interface and fifteen months after inception of the interface was analyzed. Using a list of mammogram result terms as a standard, the data quality was rated as high, medium, or low. A high-quality entry required the use of a correctly spelled standard term. Medium-quality entries used a correctly spelled abbreviated or non-standard term and low quality entries were either misspelled, blank, or correctly spelled terms not related to mammography. For null entries in the post-interface period, it was determined whether the woman had a mammogram at our facility and if she had, radiology registration data were analyzed to determine whether the primary care physician had been identified correctly.

Results: There were 843 entries during the pre-interface period and 861 entries during the post-interface period. High quality entries were present in 350 (41.6%) and 552 (63.8%), medium quality in 4 (0.5%) and 1 (0.1%), low quality in 488 (58.0%) and 308 (35.8%) entries during the pre-interface and post-interface periods, respectively. Blank entries decreased from 468 (55.5%) to 308 (35.8%) after creation of the interface. In the post-interface period, in 90 of 308 (29.2%) of the blank entries, the patient had had a mammogram performed at our facility; in 100% of

these 90 entries, the mammogram had been ordered by a provider from another practice. In these instances, either no primary care provider or an incorrect primary care provider was identified at the time of registration in the radiology department.

Conclusions: A BIRADS-EHR interface significantly improved the quality of mammogram result entries in an electronic health record with high reliability. However, radiology registration processes ultimately determine whether a result is interfaced to a primary care physician. Assuring high quality mammogram result data in EHRs requires attention to both technical and process details.

Introduction

American physicians and healthcare systems continue to lag behind previously recommended goals of transitioning to electronic health records (EHRs) for patient care(Linder, Ma, Bates, Middleton, & Stafford, 2007). One need only look back to the 1991 Institute of Medicine patient record study report which recommended 100% EHR usage by the year 2000 to know where we stand (Dick, 1991). The Center for Disease Control and Prevention's latest National Ambulatory Medical Care Survey, in fact, estimates that 43.9% of office-based physicians use an EHR in some way, 20.5% have basic systems, and only 6.3% have fully-functional systems (Hsiao et al., 2010). The American Recovery and Reinvestment Act of 2009 allocated $19 billion to health information technology, with a small portion of this money directed towards financial incentives to physicians to adopt EHRs (Federowicz, Grossman, Hayes, & Riggs, 2010; Klein, 2010). This funding has provided impetus for physicians to implement EHRs in their offices (Blumenthal, 2009). Even though regulators and politicians stress the EHR's role in improving quality of health care, there is little evidence to date that EHRs improve care (Linder et al., 2007; Zhou et al., 2009).

In reality, EHR adoption in the ambulatory setting is a complex and expensive process that requires a thorough analysis of workflow and often necessitates redesign of ingrained office procedures (Miller & Sim, 2004). There remain concerns regarding information security, objections to sharing data with other providers, and discomfort with the change process (Loomis, Ries, Saywell, & Thakker, 2002). Cost remains prohibitive for many, as does a lack of access to internal information technology support staff (Bramble et al., 2010). However, providers who already dedicate significant time and resources to manage their patients can leverage their EHR investment to improve care. For example, Baron, *et al*. showed a 10% improvement in

screening mammography rates using an EHR and a quality improvement process at a cost of $34 per patient receiving a new mammogram (Baron, 2007). In the appropriate age groups and clinical settings, this increased mammography rate should, increase the detection of cancers at an earlier stage, thereby improving outcomes for the patient and improving resource utilization for the system.

A common assumption is that clinical documentation contained in an EHR is available for analysis through a database query. In reality, most information is stored in a narrative format, and not as discrete data (Pincus, Mandelin, & Swearingen, 2009). "Free-texting" information into an EHR has been shown to produce low quality documentation, even in countries with heavy governmental regulation of medical record-keeping (Vainiomäki, Kuusela, Vainiomäki, & Rautava, 2008). A more significant problem is whether information recorded in an EHR accurately reflects the status and care of patients. In a review of 26 published studies on the accuracy of data in computerized patient records, researchers analyzed the correctness and completeness of diagnoses, medications, immunizations, procedures and demographic data reported in these studies (Hogan & Wagner, 1997). Correctness and completeness ranged from 67-100% and 30-100%, respectively. While it is clear that some of the data recorded in EHRs is reliable, data queries often provide unreliable results. In a study of coronary artery disease quality measures (Persell, Wright, Thompson, Kmetik, & Baker, 2006), 15-81% of quality failures determined by EHR data query were found to have actually met the quality measure after review of unstructured chart documentation. Nonetheless, entering data in a structured format has been shown to improve data quality and ability to generate reports on the data (Månsson, Nilsson, Björkelund, & Strender, 2004; Thiru, Hassey, & Sullivan, 2003). Even if a practice focuses on consistent, quality documentation, the complexity of quality improvement measures pose additional challenges. An analysis of the Rand Corporation's Quality Assessment Tools system determined that about 50% of quality indicators would not be easily measured by data

typically stored in EHRs and another 25% of the indicators would require additional source data outside of that available in an EHR (Roth, Lim, Pevnick, Asch, & McGlynn, 2009).

An important indicator of the quality of care in a primary care practice is the degree of compliance with evidence-based preventive health measures. Screening women ages 50-65 years for breast cancer with mammography annually is recommended by national guidelines ("Practice bulletin no. 122," 2011, "Screening for breast cancer," 2009) and some guidelines recommend (or recommend a discussion about screening) mammography screening begin at age 40 ("Practice bulletin no. 122," 2011; Qaseem et al., 2007). In the author's internal medicine ambulatory practice, there was an interest to track mammography screening in effort to improve screening rates. Reports obtained via query of the EHR database, however, were found to be unreliable as many women who had current mammography screening documented were misclassified as overdue and some women who the report listed as up-to-date on mammography were actually overdue. On review of patient charts, it was evident that mammogram reports were often available, but the results had not been documented in a structured fashion. In many cases, when structured documentation had been completed, the terms used were confusing or unconventional. In an effort to simplify mammogram result documentation and improve data quality, it was postulated that a standardized set of terms would lead to more reliable documentation. The Breast Imaging Results And Data System (BI-RADS) consists of a standardized reporting lexicon and an outcomes monitoring tool that radiologists use to track mammogram results (D'Orsi, Mendelson, & Ikeda, 2003). There are 7 result codes (BI-RADS 0-6), each with a standardized description (Table 1). The BI-RADS classification scheme has been shown to be a reliable predictor of both benignity and malignancy of mammographic findings (Obenauer, Hermann, & Grabbe, 2005; Orel, Kay, Reynolds, & Sullivan, 1999). The radiologists at The Reading Hospital were already using this classification system to interpret mammograms and a BI-RADS code was being assigned to each mammogram. The radiology department was using this structured

interpretation system to assure that women with abnormal mammograms received appropriate follow up.

Table 1 – BI-RADS Classification and truncated interfaced result

BI-RADS Category	Description	Interfaced Result
0	Mammographic Assessment is Incomplete	Incomplete
1	Negative	Negative
2	Benign finding(s)	Benign Finding(s)
3	Probably Benign Finding—Initial Short-Interval Follow-Up Suggested	Probably Benign
4	Suspicious Abnormality – Biopsy Should Be Considered	Suspicious
5	Highly Suggestive of Malignancy—Appropriate Action Should Be Taken	Highly Suggest Mal
6	Known Biopsy-Proven Malignancy—Appropriate Action Should Be Taken	Biopsy-Proven Mal

The research hypothesis was that creating a BI-RADS results interface with the EHR would have no impact on the quality of structured mammogram result documentation in the EHR. This report contains an analysis of the impact of a BI-RADS-EHR interface on the quality of entries in the mammography field of the EHR.

Materials and Methods

An exemption from institutional review was received for this project from the Reading Hospital.

Setting

The practice setting was a four-physician/one nurse practitioner (NP) academic faculty practice affiliated with a large community hospital internal medicine residency program. Although residents and medical students rotate through the office, the patients identify the faculty or the NP as their primary care provider. Most patients have private insurance or Medicare. The majority of female patients receive their gynecologic care from private community gynecologists who usually assume the responsibility for the performing patients' breast exams and ordering screening mammograms. The providers order mammography for many of the patients who no longer see a gynecologist. The majority of patients receive screening mammography through the hospital's radiology department.

Electronic Health Record

The practice has used an EHR since October 2005 (GE Centricity Physician Office 2005, Certification Commission for Healthcare Information Technology-certified in 2006, London, United Kingdom). All providers have used the EHR since its inception, and disease-specific templates that facilitate structured documentation of care, including health maintenance services are available. Even though structured documentation is available for most types of encounters, much of the care is documented in free-text fashion. Cancer screening and immunizations can readily be documented with check boxes or dropdown menus (Figure 1). The EHR has a flowsheet function that facilitates structured entry of data which can subsequently be displayed in a reverse chronologic fashion (Figure 2). During the training process, providers and clinical staff were instructed to document the results of preventive services such as mammography and colonoscopy by using the flowsheet function. If the report was available, the actual interpretation was to be entered into the structured field. In the case of mammography, even though there often

was no text report readily available report in the EHR, women frequently reported having had a mammogram at some point within the preceding year. In these instances, providers and clinical staff often would enter "done," "negative," or other terminology (see Table 3 in Appendix). Frequently, a text report was available in the chart but the mammogram field in the flowsheet was not updated. Patient records with blanks or "null" entries in the mammogram field are problematic because they are misclassified as not having had a mammogram by a data query.

Figure 1 The EHR flowsheet displaying preventive care

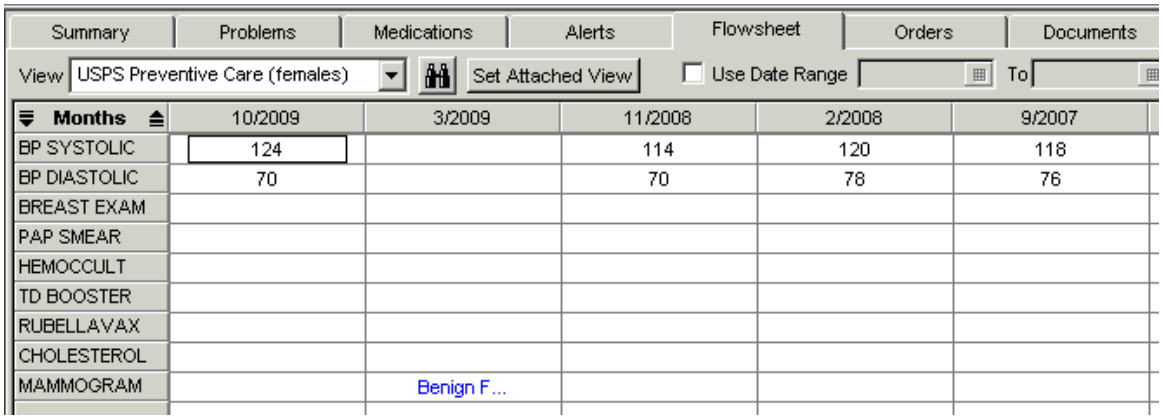
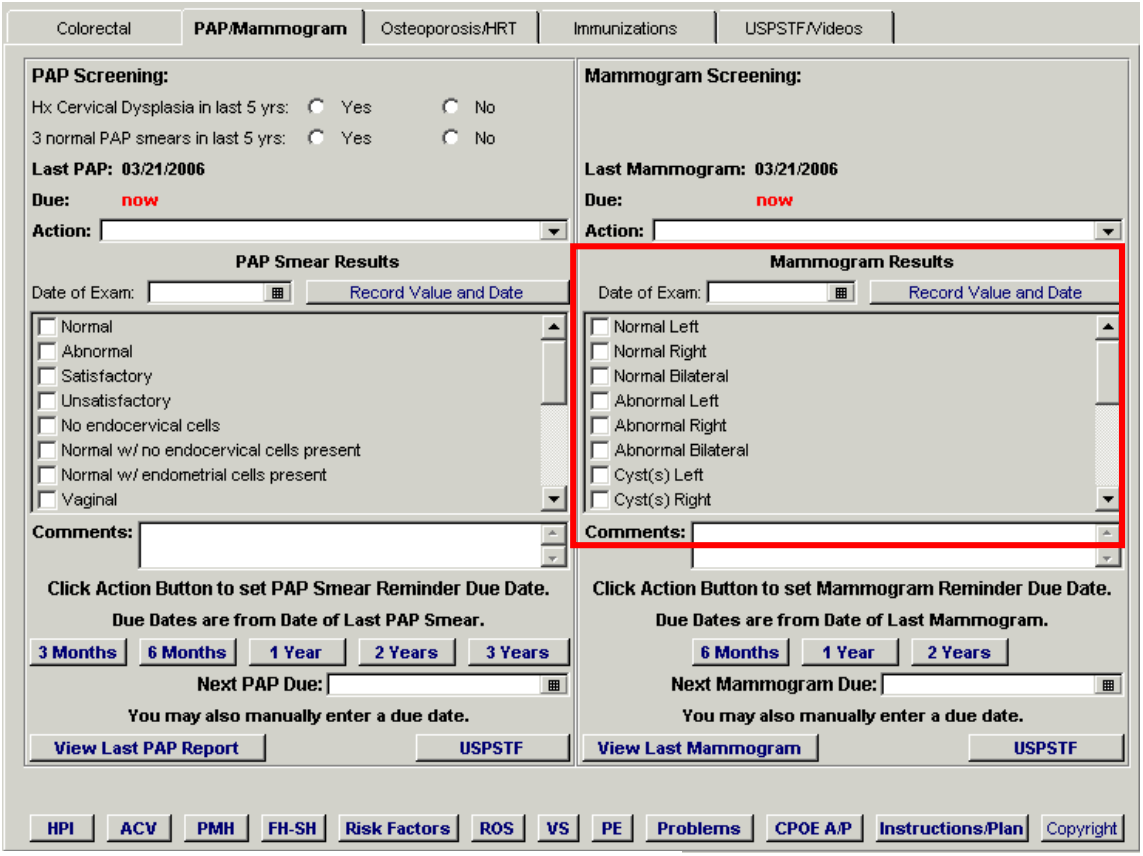


Figure 2 EHR form for preventive care documentation



Copyright 2003-2008 General Electric Company (used with permission)

BI-RADS-EHR Interface

Registration procedures of The Reading Hospital Radiology Department determine which providers receive a radiology result reports. The ordering physician always receives a result, but the family physician only receives a result upon patient request. Thus, it is possible for a patient to have a mammogram in our facility ordered by a provider other than the family physician, e.g., a gynecologist and for the family physician to have no record of the mammogram. Radiologists assign a BI-RADS category to each mammogram performed and this structured result is stored in a Siemens Radiology Information System (RIS) database. The radiology department tracks the status of mammograms requiring follow up (BI-RADS categories 0 and 3-6). Using the Siemens OPENLink™ interface engine, patient identifiers and the BI-RADS results were interfaced between the RIS database and the Centricity EHR. Because of a limitation in the number of

characters that could be passed into the result field, the BI-RADS codes were truncated (see "Interfaced Result" in Table 1). The BI-RADS result code was mapped to the MAMMOGRAM "observation term" (Centricity's designation for the database fields that store clinical results) in the EHR. After successful interface testing, the BI-RADS result report was interfaced along with a separate text report for each mammogram performed at a Reading Hospital facility starting in September 2007. The BI-RADS result report was delivered to the EHR as a "signed result" to obviate the need for providers to sign two reports for each mammogram.

Judging Data Quality

To assess the quality of documentation of screening and diagnostic mammogram results all entries and null (blank) entries in the EHR flowsheet were analyzed for a 15-month period from June 12, 2006 to September 12, 2007 in women 40-65 years of age (before the BI-RADS interface) and from September 13, 2007 to December 13, 2008 (after the BI-RADS interface). Other than the BI-RADS lexicon which is used primarily by radiologists in their reports, there is no standardized method for documenting mammographic results in an EHR. Thus, a list of terms deemed to be likely to be used by clinicians to document mammogram results was compiled and the following data quality criteria were used:

High quality entries (both required):

1. Correct spelling
2. Not abbreviated (except BI-RADS interfaced terms)

Acceptable terms for high quality:

i. Any BI-RADS term

ii. Normal

iii. Abnormal

iv. Negative

v. Benign

vi. Cancer

vii. Refused (Refuses)

viii. Deferred (Defers)

ix. Cyst

x. Microcalcification or calcification

xi. Biopsy

xii. Surgical or surgery

xiii. Mass

xiv. Suspicious

Criteria for medium quality entry (either criterion sufficed for medium quality designation):

1. Correct spelling of a term not defined as high quality
2. Abbreviation of an acceptable term (other than a BI-RADS abbreviation)

Criteria for low quality entry (any of the three criteria sufficed for low quality designation):

1. Misspelled
2. Null (no entry during study period)
3. Correctly spelled but makes no sense in the context of mammography

If a reviewer encountered a term not listed as one of the acceptable terms, two additional reviewers adjudicated whether the entry should be categorized as low, medium, or high. A data quality rating for each entry and null entry was assigned for both study periods. Entries in the mammogram field for a given patient were compared with the result contained in the report to assure accuracy of flowsheet documentation. Entries for all women were compared across the two study periods but not for individual women themselves across the two study periods, i.e., an

individual woman's entries were not compared across the study periods. When an entry was null, the hospital radiology results system was searched to see if the patient had actually had a mammogram but no result was received.

Statistical Analysis

Using SPSS, a chi-square analysis of the data entry quality, null entries, and incomplete mammogram follow-up before and after the implementation of the interface was performed. Given the low number of medium quality entries in both pre- and post-interface periods (5 combined), they were excluded from chi-square analysis. Microsoft Excel 2010 (Redmond, WA) was used to generate a Pareto analysis of mammogram entries before and after the mammogram interface.

Results

There were 843 entries during the pre-interface period and 861 entries during the post-interface period (Table 2). A Pareto analysis of mammogram entries in the pre-interface period revealed that 9 terms accounted for 90% of the entries and 80 discrete terms were used to document mammogram results. In the post-interface period, 5 terms accounted for 90% of the entries and 27 discrete terms were used to document results. High quality entries were present in 41.5% and 63.8%, medium quality in 0.5% and 0.1%, low quality in 58.0% and 35.8% during the pre-interface and post-interface periods, respectively ($p<0.0001$). Null (blank) entries decreased from 468 (58.0%) to 308 (35.8%) after the interface. In the pre-interface period, 54.7% of the null entries represented patients that had had a mammogram at our facility. In the post-interface period, this was reduced to 29.2% of the null entries ($p<0.0001$). Incomplete mammograms represented 6.3% of all entries in both interface periods. There was no difference in appropriate

30-day follow up for incomplete mammograms between both groups (96.2% pre-interface and 88.9% post-interface, p=0.2815).

Table 1 Results of data quality analysis

	Pre-BI-RADS, n (%)	Post-BI-RADS, n (%)
Number of entries analyzed	843	861
High quality entries*	350 (41.6)	552 (63.8)
Medium quality entries*	4 (0.5)	1 (0.1)
Low quality entries*	488 (58.0)	308 (35.8)
Null (blank) entries	468 (55.5)	308 (35.8)
Null entries despite evidence of mammography at our facility¶	256 (54.7)	90 (29.2)
Null entries despite mammogram being performed at other facility during study period or unknown status¶	212 (45.3)	218 (70.8)

% applies only to values after 1st row

*P value for entry quality <0.0001 (medium quality entries excluded from analysis as there were only 5 total)

¶ P value for null entry analysis <0.0001

Figure 3

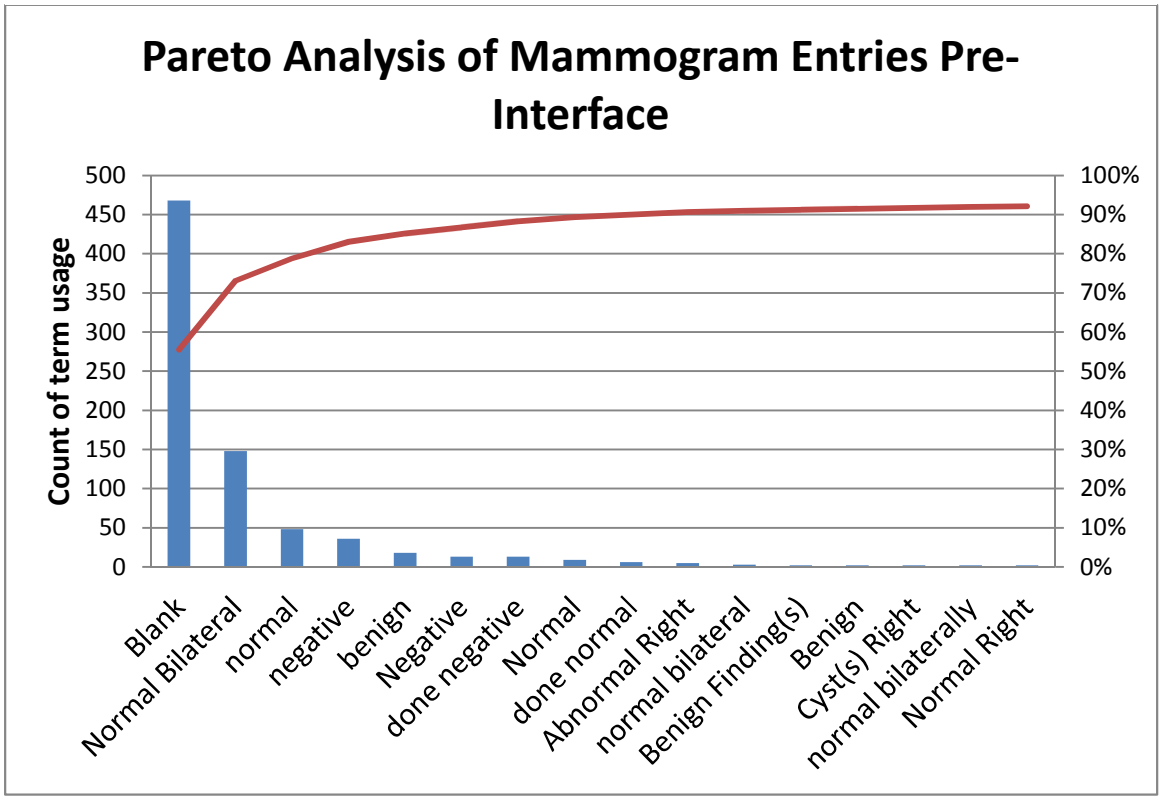
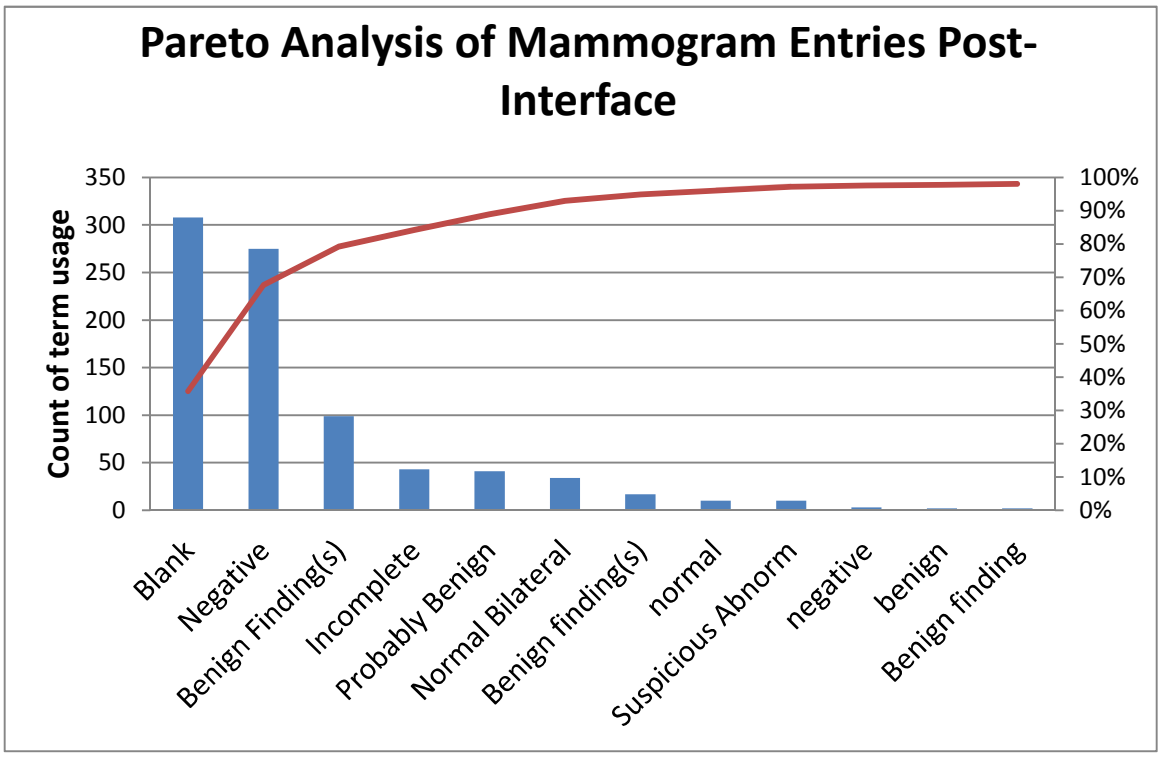


Figure 4



Discussion

The data clearly show that a BI-RADS-EHR interface improved the quality of mammogram result data documented in the EHR. To date, researchers have focused on assessing the impact of EHRs on the quality of care (Keyhani et al., 2008; Linder et al., 2007; Miller & Sim, 2004; Zhou et al., 2009) and data quality in HIV care,(Forster et al., 2008) but little research has focused on which components of an EHR improve data quality and subsequently the quality of patient care. In a study of New York City's primary care information project, researchers analyzed whether EHR data on 11 quality measures was documented in a fashion that facilitated "automated quality measurement" (Parsons, McCullough, Wang, & Shih, 2012). The study included EHR data from 57 practices (89.9% were primary care providers) and revealed that the presence of documentation formatted to facilitate automated quality measurement varied from 10.7% (breast cancer screening) to 99.9% (blood pressure documentation). In a review of literature on the use of EHRs in health outcomes research, Dean *et al.* reported that 24% of the studies reviewed included data validation and that EHR data concurrence with a reference standard (most often the paper chart) was over 70% in all but one study (Dean et al., 2009). A study performed at Intermountain Health Care demonstrated that high quality of laboratory results in EHRs can be achieved by using structured data entry to transcribe paper results for transplant patients (Staes et al., 2006). In the United Kingdom, other researchers have used data quality probes to assess the quality of care but these techniques used heuristics to test for conditions that should or should not be present, e.g., every diabetic not on insulin should be a type 2 diabetic rather than assessing the actual quality of data (Brown, Harwood, & Brantigan, 2001). A search of the PubMed, Scopus, and IEEE Xplore databases yielded no studies on the impact of electronic interfacing of BI-RADS to EHRs on mammogram result data quality. This study is the first to show that data interfaces can improve the quality of EHR data.

Another significant impact of the interface was that it reduced the total number of discrete terms used to document mammogram results. A smaller number of terms should make writing a query simpler and could improve the accuracy of the reports produced. Nonetheless, the fact that 27 different terms were used to describe mammography results in the post-interface period, when a validated lexicon with 6 terms exists, suggests an opportunity for further improvement in the documentation process.

It was surprising to find that a significant number of null entries during the post-interface period occurred in the context of a woman actually having had a mammogram in our facility. An analysis of all 90 post-interface null entries of mammograms that were performed at hospital facilities revealed the mammograms had been ordered by a provider from another practice affiliated with the institution. In each of these instances, during the registration process in radiology, no provider from the faculty practice was identified as a potential recipient of the mammography result. Since a provider must be identified at the time of registration in order to receive a result and because the practice no longer receives paper radiology results, no mammography result was interfaced. There currently is no electronic method in place to track the performance of the interface but on the basis of this manual analysis, there was no evidence of interface failure in these 90 post-interface null entries.

Improved data quality should lead to better patient management and overall quality of care. An accurate assessment of the adherence to screening guidelines is critical to assist in the adherence to screening guidelines. Not only would providers be able to receive accurate feedback about their performance but a practice could also implement a systematic process to improve screening rates (Arroyave, Penaranda, & Lewis, 2011; Morère et al., 2011).

Summary and Conclusions

Mammography result data quality can be improved by a BI-RADS-EHR interface. Most health systems that use BI-RADS for mammography reporting should be able to interface their mammogram results accurately to EHRs. However, local registration procedures at mammography facilities may prevent a result from reaching the electronic health record. Physicians who use EHRs, EHR administrators, and radiologists need to coordinate their policies so that patient data can accurately flow to each EHR. A medical practice should either use BI-RADS or develop a standardized lexicon and process to document mammography results that are not interfaced as data, e.g., mammogram reports received as text either in paper or electronic format. Healthcare systems should set policies for standardized documentation of mammogram results to assure accurate reporting which in turn can be used to improve mammography screening rates for a population of women and minimize the delay in evaluation of abnormal mammograms.

References

Arroyave, A. M., Penaranda, E. K., & Lewis, C. L. (2011). Organizational change: a way to increase colon, breast and cervical cancer screening in primary care practices. *Journal of Community Health*, *36*(2), 281–288. doi:10.1007/s10900-010-9309-7

Baron, R. J. (2007). Quality improvement with an electronic health record: achievable, but not automatic. *Annals of Internal Medicine*, *147*(8), 549–552.

Blumenthal, D. (2009). Stimulating the adoption of health information technology. *The New England Journal of Medicine*, *360*(15), 1477–1479. doi:10.1056/NEJMp0901592

D'Orsi, C., Mendelson, E., & Ikeda, D. et al. (2003). BI-RADS: Mammography, 4th edition in: D'Orsi CJ, Mendelson EB, Ikeda DM, et al: Breast Imaging Reporting and Data System: ACR BI-RADS – Breast Imaging Atlas. American College of Radiology.

Dean, B. B., Lam, J., Natoli, J. L., Butler, Q., Aguilar, D., & Nordyke, R. J. (2009). Review: use of electronic medical records for health outcomes research: a literature review. *Medical Care Research and Review: MCRR*, *66*(6), 611–638. doi:10.1177/1077558709332440

Dick, R. (1991). The Computer-Based Patient Record: An Essential Technology for Health Care, Revised Edition. Retrieved January 28, 2012, from http://books.nap.edu/openbook.php?record_id=5306

Forster, M., Bailey, C., Brinkhof, M. W. G., Graber, C., Boulle, A., Spohr, M., Balestre, E., et al. (2008). Electronic medical record systems, data quality and loss to follow-up: survey of antiretroviral therapy programmes in resource-limited settings. *Bulletin of the World Health Organization*, *86*(12), 939–947.

Hogan, W. R., & Wagner, M. M. (1997). Accuracy of Data in Computer-Based Patient Records. *Journal of the American Medical Informatics Association*, *4*(5), 342–355. doi:10.1136/jamia.1997.0040342

Hsiao, C., Beatty, P., Hing, E., Woodwell, D., Rechsteiner, E., & Sisk, J. (2010). Products - Health E Stats - EMR and EHR Use by Office-based Physicians - Preliminary 2010. Retrieved March 14, 2011, from http://www.cdc.gov/nchs/data/hestat/emr_ehr_09/emr_ehr_09.htm

Keyhani, S., Hebert, P. L., Ross, J. S., Federman, A., Zhu, C. W., & Siu, A. L. (2008). Electronic health record components and the quality of care. *Medical Care*, *46*(12), 1267–1272. doi:10.1097/MLR.0b013e31817e18ae

Linder, J. A., Ma, J., Bates, D. W., Middleton, B., & Stafford, R. S. (2007). Electronic health record use and the quality of ambulatory care in the United States. *Archives of Internal Medicine*, *167*(13), 1400–1405. doi:10.1001/archinte.167.13.1400

Loomis, G. A., Ries, J. S., Saywell, R. M., Jr, & Thakker, N. R. (2002). If electronic medical records are so great, why aren't family physicians using them? *The Journal of Family Practice*, *51*(7), 636–641.

Månsson, J., Nilsson, G., Björkelund, C., & Strender, L.-E. (2004). Collection and retrieval of structured clinical data from electronic patient records in general practice. A first-phase study to create a health care database for research and quality assessment. *Scandinavian Journal of Primary Health Care*, *22*(1), 6–10.

Miller, R. H., & Sim, I. (2004). Physicians' use of electronic medical records: barriers and solutions. *Health Affairs (Project Hope)*, *23*(2), 116–126.

Morère, J.-F., Pivot, X., Viguier, J., Blay, J.-Y., Calazel-Benque, A., Coscas, Y., Roussel, C., et al. (2011). Breast cancer screening in women aged 50-74 years: is there room for improvement? *European Journal of Cancer Prevention: The Official Journal of the European Cancer Prevention Organisation (ECP)*, *20 Suppl 1*, S8–S12. doi:10.1097/01.cej.0000391562.18512.4a

Parsons, A., McCullough, C., Wang, J., & Shih, S. (2012). Validity of electronic health record-derived quality measurement for performance monitoring. *Journal of the American Medical Informatics Association: JAMIA*. doi:10.1136/amiajnl-2011-000557

Persell, S. D., Wright, J. M., Thompson, J. A., Kmetik, K. S., & Baker, D. W. (2006). Assessing the validity of national quality measures for coronary artery disease using an electronic health record. *Archives of Internal Medicine*, *166*(20), 2272–2277. doi:10.1001/archinte.166.20.2272

Pincus, T., Mandelin, A. M., 2nd, & Swearingen, C. J. (2009). Flowsheets that include MDHAQ physical function, pain, global, and RAPID3 scores, laboratory tests, and medications to monitor patients with all rheumatic diseases: an electronic database for an electronic medical record. *Rheumatic Diseases Clinics of North America*, *35*(4), 829–842, x–xi. doi:10.1016/j.rdc.2009.10.018

Practice bulletin no. 122: Breast cancer screening. (2011).*Obstetrics and Gynecology*, *118*(2 Pt 1), 372–382. doi:10.1097/AOG.0b013e31822c98e5

Qaseem, A., Snow, V., Sherif, K., Aronson, M., Weiss, K. B., & Owens, D. K. (2007). Screening mammography for women 40 to 49 years of age: a clinical practice guideline from the American College of Physicians. *Annals of Internal Medicine*, *146*(7), 511–515.

Roth, C. P., Lim, Y.-W., Pevnick, J. M., Asch, S. M., & McGlynn, E. A. (2009). The challenge of measuring quality of care from the electronic health record. *American Journal of Medical Quality: The Official Journal of the American College of Medical Quality*, *24*(5), 385–394. doi:10.1177/1062860609336627

Screening for breast cancer: U.S. Preventive Services Task Force recommendation statement. (2009).*Annals of Internal Medicine*, *151*(10), 716–726, W–236. doi:10.1059/0003-4819-151-10-200911170-00008

Staes, C. J., Bennett, S. T., Evans, R. S., Narus, S. P., Huff, S. M., & Sorensen, J. B. (2006). A case for manual entry of structured, coded laboratory data from multiple sources into an

ambulatory electronic health record. *Journal of the American Medical Informatics Association: JAMIA*, *13*(1), 12–15. doi:10.1197/jamia.M1813

Thiru, K., Hassey, A., & Sullivan, F. (2003). Systematic review of scope and quality of electronic patient record data in primary care. *BMJ (Clinical Research Ed.)*, *326*(7398), 1070. doi:10.1136/bmj.326.7398.1070

Vainiomäki, S., Kuusela, M., Vainiomäki, P., & Rautava, P. (2008). The quality of electronic patient records in Finnish primary healthcare needs to be improved. *Scandinavian Journal of Primary Health Care*, *26*(2), 117–122. doi:10.1080/02813430701868806

Zhou, L., Soran, C. S., Jenter, C. A., Volk, L. A., Orav, E. J., Bates, D. W., & Simon, S. R. (2009). The relationship between electronic health record use and quality of care over time. *Journal of the American Medical Informatics Association: JAMIA*, *16*(4), 457–464. doi:10.1197/jamia.M3128

Appendix

Table 3 Listing of all terms used to document mammogram results

Mammogram Entry	Pre-interface	Post-interface	Total
Blank	468	308	776
Normal Bilateral	148	34	182
normal	48	10	58
negative	36	3	39
benign	18	2	20
Negative	13	275	288
done negative	13	0	13
Normal	9	1	10
done normal	6	0	6
Abnormal Right	5	0	5
normal bilateral	3	1	4
Benign Finding(s)	2	99	101
Benign	2	0	2
Cyst(s) Right	2	0	2
normal bilaterally	2	0	2
Normal Right	2	0	2
stable	2	0	2
Abnormal Left	1	1	2
Category 2	1	1	2
02/08/07	1	0	1
1/12/06	1	0	1
1/18/07-benign	1	0	1
1/30/07-normal	1	0	1
1/30/17-normal	1	0	1
1/31/07 Benign	1	0	1
1/6/05-normal	1	0	1
10/17/05	1	0	1
11/22/06	1	0	1
12/06	1	0	1
12/20/06 negative	1	0	1
2/27/07 neg mammogram	1	0	1
2/5/07-normal	1	0	1
2003	1	0	1
2004	1	0	1
2004-normal	1	0	1
2005	1	0	1
2007 elsewhere	1	0	1
4/20/2004	1	0	1
7/5/06	1	0	1
abnormal	1	0	1
Abnormal	1	0	1

abnormal bilat/dx mammo and US done 10/31/06	1	0	1
abnormal screen/7mm mass LIQ R breast	1	0	1
BENIGN	1	0	1
benign - done at St Joe's	1	0	1
benign (category 2)	1	0	1
benign 1/8/07	1	0	1
benign mammogram, right cyst	1	0	1
benign screening	1	0	1
benign stable	1	0	1
benign/done at St. Joe's	1	0	1
Cyst(s) Left, Cyst(s) Right	1	0	1
diag R - benign on 1/23/07	1	0	1
done abnormal	1	0	1
done elsewhere	1	0	1
done microcalcification	1	0	1
done-normal	1	0	1
Done-normal	1	0	1
Dx mammo 1/15/07 - normal	1	0	1
dx mammo 1/16/07 - normal	1	0	1
elsewhere	1	0	1
elsewhere 2/07 normal	1	0	1
elsewhere 2005	1	0	1
elsewhere 2005 normal	1	0	1
elsewhere Dec. 2006	1	0	1
elsewhere Summer 2007	1	0	1
L diagnostic normal/U/S normal	1	0	1
left diagnostic benign	1	0	1
left dx mammo benign	1	0	1
Neg bilaterally	1	0	1
negative screening mammo	1	0	1
new microcalcifications	1	0	1
no abn	1	0	1

normal elsewhere	1	0	1
normal screening	1	0	1
Oct.2006 normal	1	0	1
probable benign diagnostic mammo	1	0	1
probable benign dx mammo/repeat in 6 months	1	0	1
R benign/L-incomplete	1	0	1
Refused	1	0	1
stable benign	1	0	1
Incomplete	0	43	43
Probably Benign	0	41	41
Benign finding(s)	0	17	17
Suspicious Abnorm	0	10	10
Benign finding	0	2	2
Category 1	0	2	2
per pt. normal	0	2	2
done at St. Joseph's - normal	0	1	1
Incomplete Benign Finding(s)	0	1	1
Incomplete Suspicious Abnorm	0	1	1
neg - done at Ephrata	0	1	1
neg/normal	0	1	1
negative Category 1	0	1	1
normal accord. to pt.--done at Health South	0	1	1
normal per patient	0	1	1
Suspicious Abnrom	0	1	1
Totals	843	861	1704