

The impact of the implementation of a clinical decision support system on the quality of healthcare services in a primary care setting

Ahmed Sherif Mahmoud, Abdullah Alkhenizan, Mohammed Shafiq, Suad Alsoghayer

Department of Family Medicine and Polyclinics, King Faisal Specialist Hospital and Research Centre, Riyadh, Saudi Arabia

ABSTRACT

Background: In July 2015, King Faisal Hospital Family Medicine clinics (KFH-FMC) successfully implemented a paperless, fully integrated, electronic healthcare system. The aim of this study is to evaluate the impact of moving to a fully integrated electronic medical record system, with clinical decision support (CDS) systems, on the quality of healthcare services in a primary care setting. We aim to evaluate the impact of CDS on clinical outcomes such as screening and diagnosis of breast and colorectal cancers, as well as the management of chronic diseases such as diabetes and hypertension, and the uptake of immunizations. **Inclusion and Exclusion Criteria:** Our study included all adult patients, over the age of 18, registered in the Family Medicine clinic linked to King Faisal Hospital, seen between January 2012 and December 2018. **Design:** Retrospective cohort study. **Setting:** Family Medicine clinics at King Faisal Hospital (KFH-FMC). **Materials and Methods:** Data were collected retrospectively from the electronic health records of all adult patients above 18 years of age, who were seen in KFH-FMC between January 2012 and December 2018. We analyzed several processes of care and a number of clinical outcomes, comparing results for the three and a half years before CDS implementation with the three and a half years after implementation. Data collected included blood pressure measurements, lipid levels, HbA1c for diabetic patients, screening tests done, including PAP smear, mammogram, fecal occult blood tests, and bone densitometry. Other data included cancer diagnoses and immunizations received. **Results:** Significant increases were found in adult vaccine uptake ranging from an 11-fold increase in influenza uptake, to a 22-fold increase in pneumococcal 23 uptake. The uptake of all the cancer screening tests increased (FOB 66%, mammogram 33%, PAP smear 16%). Diagnoses of breast and colorectal cancer showed significant increases. Breast cancer diagnoses increased from 2 to 14, and colorectal cancer from 3 to 11. No significant improvement was found in chronic disease outcomes. **Discussion:** The electronic health record with CDS led to significantly improved uptake of immunizations and screening tests, with earlier diagnoses of breast and colon cancer. Evidence of improvement in chronic disease outcomes is still lacking.

Keywords: Accreditation, electronic health record, electronic medical records, health informatics, immunizations, retrospective cohort, screening

Introduction

Electronic Medical records (EMR) systems, when designed well and utilized appropriately, have the potential to transform healthcare delivery.^[1] Electronic health records can lead to better and safer healthcare. It can help clinicians to accurately share data with other clinicians and to track patient encounters, current problems,

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Address for correspondence: Dr. Ahmed Sherif Mahmoud, Consultant, Family Medicine, King Faisal Specialist Hospital and Research Center, MBC 62, PO Box - 3354, Riyadh - 11211, Saudi Arabia.
E-mail: mahmedsherif@kfshrc.edu.sa

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and active medications. They can also streamline order entry and electronic prescribing in a fully integrated electronic system.^[2]

Technology used in healthcare should improve patient care, improving outcomes, saving time and money, and therefore increasing efficiency.^[3] Some studies have shown improved outcomes in diabetes care linked to implementation of integrated electronic services,^[4] while other studies have shown that the use of electronic medical records in primary care services improve processes of care, leading to structural benefits like improved documentation, better legibility, accessibility, and cost saving, without clear evidence of significant improvement in clinical health-related outcomes,^[5,6]

Potential health benefits of electronic integration of evidence-based recommendations for preventive services, so as to identify the individual screening needs of each patient, are hugely significant. In this scenario, CDS assisted screening, chronic disease prevention, and chronic disease management would produce very favorable health benefits as well as saving significant resources due to reduced hospital stays and prevention of advanced disease.^[7]

At King Faisal Specialist Hospital (KFSH), in the family medicine clinics, we cater to the primary healthcare needs of a normal cross section of patients of all ages and social strata. The patient population that we serve is approximately 45000 patients.

In 2015, to tackle perceived under-utilization of screening and adult immunization uptake, we introduced CDS systems in our electronic health records. The aim was to establish an evidence based, user-friendly CDS tool for cancer and chronic disease screening services. CDS has been shown to modify test-ordering behavior in multiple studies.^[8] A team of healthcare professionals decided on the screening needs of the population, mostly in line with the targets set by the international, evidence-based guidelines, and in collaboration with our colleagues in healthcare informatics, we implemented CDS tools and alerts which would be triggered by the screening needs of patients based on their age and gender. The system would alert healthcare providers if the patient was due FOB testing, as well as mammogram screening, cervical smears, adult vaccinations and regular laboratory screening for diabetes, hyperlipidemia, and manual hypertension screening. CDS matches patient characteristics with up-to-date, evidence-based knowledge to generate specific requirements for each particular patient.^[9] When CDS suggested the need for a certain screening test, one click from the physician would be enough to enter the necessary order which could then be performed by the patient. This would make screening needs very clear and obvious, and the process of ordering immunizations, laboratory tests and cancer screening tests smooth and user-friendly. This is an example of an active, knowledge based CDS system, where the user is actively prompted, through pop-ups, to request necessary screening and follow up tests according to latest guidelines. In addition, the physician user is prompted to enter every unrecorded problem and new diagnosis for the patient whenever the patient is reviewed in the clinic. A diagnosis of hypertension, diabetes or hyperlipidemia would

lead to regular pop-up reminders to request relevant laboratory tests and recheck blood pressure in keeping with latest guidelines. Otherwise, the user would be prompted to request screening tests for these disorders in accordance with the most recent screening guidelines from the United States Preventive Services Taskforce (USPSTF).

As a result, in August 2015, Healthcare information and Management Systems Society (HIMSS) Analytics awarded King Faisal Hospital Family Medicine Clinic (KFH-FMC), Riyadh, Stage 7 of the Primary Care Electronic Medical Record Adoption Model (PC-EMRAM). Stage 7 signifies a fully integrated, electronic, paperless system, in an organization which is highly dependent on information technology in the provision of high-quality healthcare.^[10] The attainment of this award makes KFH-FMC the first organization to achieve Stage 7 in the Middle East and the first PC-EMRAM Stage 7 Organization outside the USA. HIMSS is a global Non-governmental organization, leading efforts to optimize healthcare through information technology.^[11]

When assessing the impact of clinical decision support technologies, there is evidence that CDS improves adult immunization rates for sustained periods of time.^[12] Elsewhere, systematic reviews have shown that a majority of CDS improved care processes in chronic disease management with less evidence for improvement in patient health.^[13] In general, evidence has demonstrated that CDS tools are extremely effective in improving health care process outcomes, but the same cannot be said about clinical patient outcomes or economic outcomes, where the data remains scarce.^[14]

Systematic reviews on the effect of CDS on management of Diabetes and other chronic diseases found only marginal improvement in clinical outcomes,^[15] with a need for further well-designed research to improve current understanding.^[16]

Evidence also exists for improved cancer screening rates with CDS technologies,^[17,18] but again no significant improvement in patient health outcomes has been demonstrated. It is this gap in the literature that we hope to address in this study, by investigating whether CDS can actually improve patient outcomes in early cancer diagnosis and management, as well as chronic disease management.

Objectives

Primary Objectives: To evaluate the impact of CDS implementation on multiple clinical outcomes, including detection and diagnosis of breast, cervical and colorectal cancers, as well as control of blood pressure, HbA1c, and lipid levels.

Secondary Objectives: To evaluate the impact of CDS implementation on multiple process of care outcomes including the uptake of adult immunizations, cervical smears, fecal occult blood tests, and mammogram screening. Adult immunizations include the influenza vaccine, herpes zoster, and the two pneumococcal vaccines, 13-valent, and 23-valent.

The ultimate aim is to evaluate the impact of CDS implementation on the uptake of cancer screening tests and immunizations, management of chronic diseases (hypertension and diabetes), and early diagnosis and treatment of breast, colorectal, and cervical cancers.

Materials and Methods

Data were collected retrospectively from electronic medical records for all adult patients above 18 years of age who were seen in KFH-FMC between January 2012 and December 2018. Data collected included blood pressure measurements, lipid levels, HbA1c for diabetic patients, screening tests done, e.g., PAP smear, mammogram and fecal occult blood tests. Other data included cancer diagnoses, and immunizations received, including influenza, herpes zoster, and the two pneumococcal vaccines.

The data in the period immediately before the implementation of the CDS systems was compared to the data for the period after the implementation of these changes.

Ethical considerations

All data were extracted from electronic medical records. Patients were not interviewed at any point and information was anonymous. Patients' names and medical record numbers were not used. UPN codes were used to ensure privacy and confidentiality.

All data and files collected were kept in a secure location under lock and key, accessible only to the research investigators. Data was all anonymized. This research proposed no interventions, clinical or otherwise. The study was primarily concerned with collecting and analyzing data, and thus the study posed no risk to patients or other participants.

The research project was conducted in accordance with the ethical principles contained in the Declaration of Helsinki (2000) and the policies of the Research Advisory Committee (RAC) at King Faisal Specialist Hospital and Research Centre, as well as the laws of the Kingdom of Saudi Arabia.

In view of the above, the research proposal was approved, and a waiver of informed consent was granted by the Institutional Review Board, the research advisory committee at King Faisal Specialist Hospital and Research Centre in Riyadh, Saudi Arabia.

Results

We compared the numbers for the 3 and a half years prior to implementation of the Health maintenance electronic CDS system, with the 3 and a half years following the implementation of the system. The results are summarized in Table 1 below. There were significant increases in the uptake of all adult vaccines, namely herpes zoster, influenza, and the two pneumococcal vaccines [see Figures 1-4 below]. Zoster uptake increased over 16-fold, from 101 to 1638. Influenza uptake increased over 11-fold from 1922 to 21250. Pneumococcal 13 uptake increased over 18-fold, from 99 to 1835. Pneumococcal 23 uptake increased over 22-fold from 20 to 452.

There were also significant increases in uptake of screening tests, namely fecal occult blood, mammogram, and cervical smear tests [see Figures 5-7]. FOB screening increased by 66% from 5848 to 9697. Mammogram uptake increased by 33% from 3158 to 4199. PAP smear screening increased by 16% from 3505 to 4078. Resulting diagnosis of colorectal cancer and breast cancer saw significant increases [see Figures 8 and 9], while there were no cervical cancer diagnoses throughout the entire period. Colorectal

Table 1: Comparing variables for 3-and-a-half-year period before CDS implementation with 3-and-a-half-year period immediately after

	January 2012 – June 2015	July 2015 – December 2018
Electronic Diagnoses Hypertension entered	751	8394
Electronic diagnoses Hyperlipidemia entered	452	6177
Electronic diagnosis Diabetes entered	958	12562
Frequency HbA1c ordered	12067	12978
Mean HbA1c for diabetics	7.9%	7.8%
Mean systolic blood pressure	116	117
Frequency LDL ordered	28851	41326
Mean LDL level	3.03	3.06
Zoster vaccine uptake	101	1638
Influenza vaccine uptake	1922	21250
Pneumococcal 13-valent vaccine uptake	99	1835
Pneumococcal 23-valent vaccine uptake	20	452
Fecal Occult blood screening uptake	5848	9697
Mammogram screening uptake	3158	4199
PAP smear uptake	3505	4078
Colorectal cancer diagnoses	3	11
Breast cancer diagnoses	2	14
Cervical cancer diagnosis	0	0

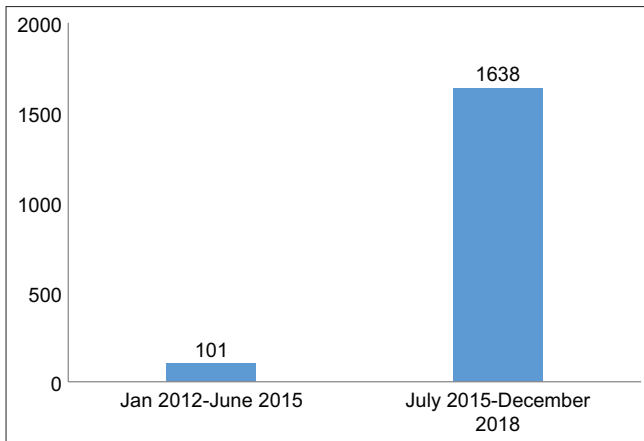


Figure 1: Zoster vaccine orders

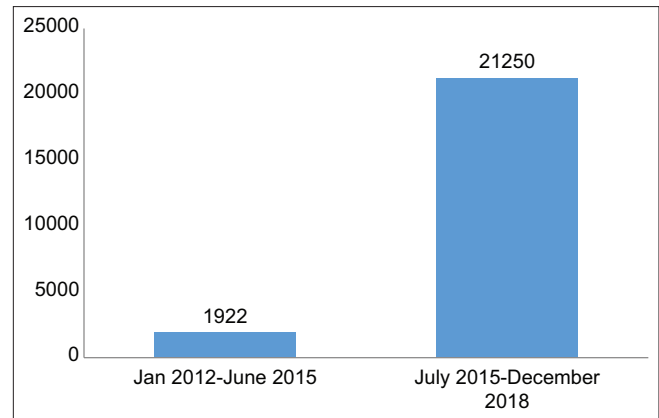


Figure 2: Influenza orders

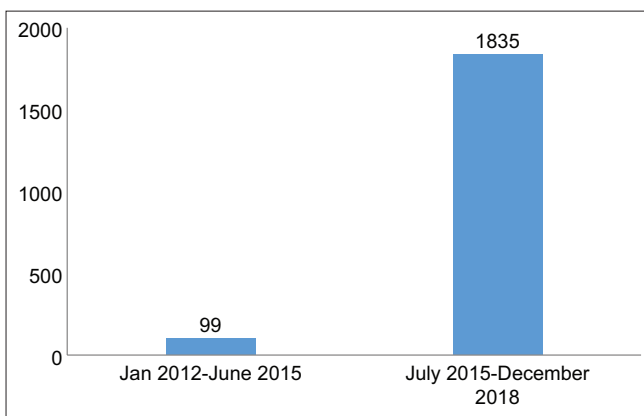


Figure 3: Pneumococcal 13 vaccine orders

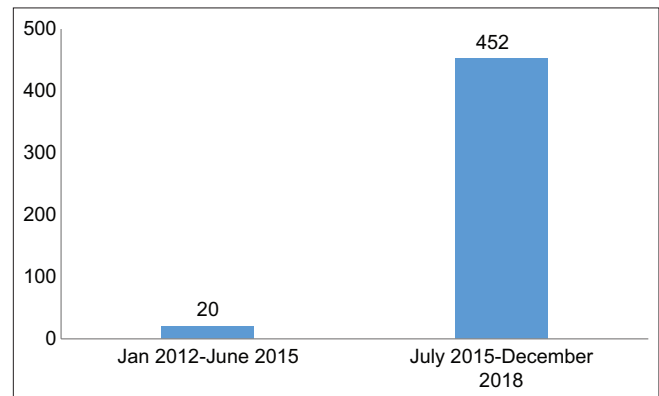


Figure 4: Pneumococcal 23 vaccine orders

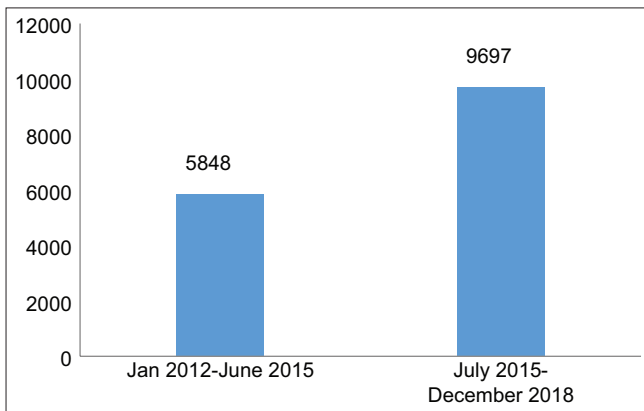


Figure 5: FOBT orders

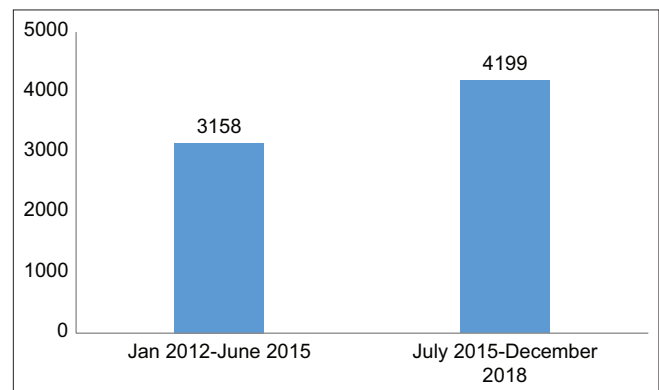


Figure 6: Mammogram orders

cancer diagnoses increased from 3, in the 3-and-a-half-year period before CDS implementation, to 11 in the 3-and-a-half-year period after CDS implementation. Breast cancer diagnoses increased from 2 to 14 in the same period.

Electronic diagnosis entry for chronic diseases significantly increased following full implementation of electronic health records, with electronic diabetes diagnosis documentation increasing from 958 to 12562, hypertension from 751 to 8394, and hyperlipidemia documentation from 452 to 6177, but no

significant changes were found in the number of orders for HbA1c, nor in patient outcomes like blood pressure levels, LDL cholesterol levels or HbA1c results. HbA1c was ordered 12067 times before and 12978 times after implementation of CDS. Mean HbA1c for diabetic patients was 7.9% prior to CDS implementation and 7.8% afterwards. Mean electronically recorded systolic blood pressure was 116 mm Hg prior to CDS implementation and 117 mm Hg afterwards. The number of orders for LDL cholesterol increased 43% from 28851 to 41326, but mean LDL level was virtually unchanged, 3.03 prior to implementation of CDS and 3.06 afterwards.

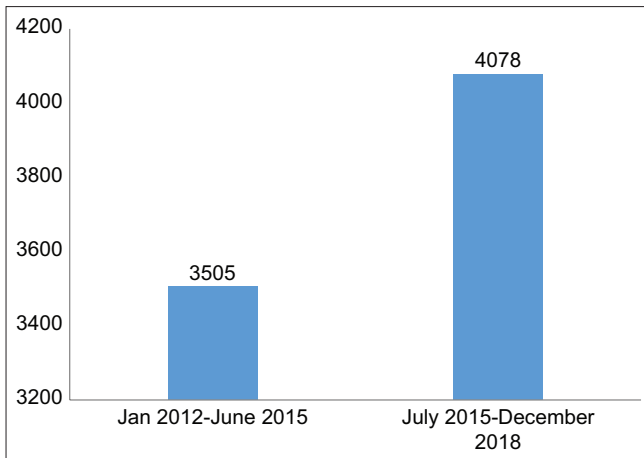


Figure 7: Cervical smears done

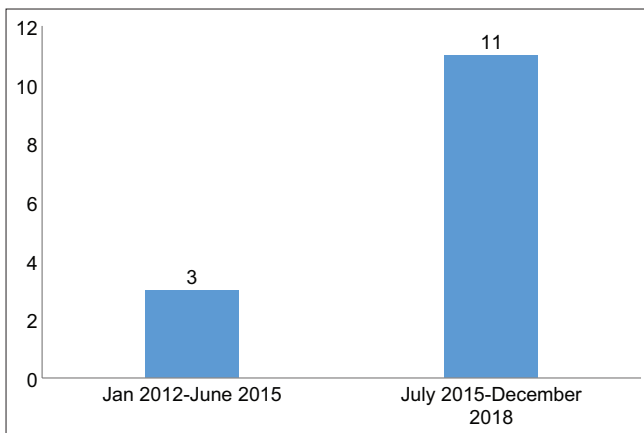


Figure 8: Colorectal cancer diagnoses

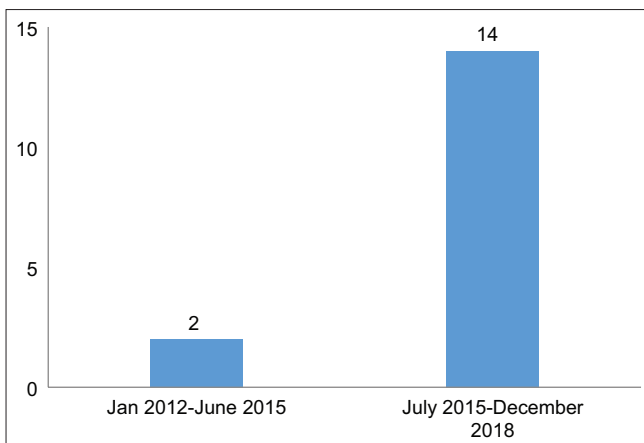


Figure 9: Breast cancer diagnoses

Discussion

Paper charts, lack of standardization, and the difficulty accessing relevant information were all part of the reason why our adult immunization and cancer screening programs were below the desired standards. The care processes implemented with the electronic medical record and CDS systems helped to standardize the process. Healthcare professionals were able to determine

which screening tests were due, and which tests had already been done and when. The technology also helped to make clear which immunizations were due, and which immunizations had already been administered and when. This led to significant increases in all the above-mentioned adult vaccination orders as well as cancer screening tests, fecal occult blood, mammography, and cervical smear. These are very important process of care outcomes. However, it was more important to see significant increases in important clinical outcomes, the diagnosis of colorectal and breast cancer. Theoretically, the more patients you screen, the more abnormalities will be picked up early and our colorectal cancer diagnosis and breast cancer diagnosis numbers certainly appear to support that. In addition, the CDS tool would help ensure that screening was being requested for the right patient groups at the right times, rather than a more haphazard approach to screening. Screening the target population, at the correct intervals, reduced waste and increased the yield of our screening program. This was illustrated in our results, where the yield for colorectal cancer screening before CDS implementation was 3 out of 5848 or 0.05%, which increased after CDS implementation to 11 out of 9697 or 0.11%. Similarly, for breast cancer screening, the yield before CDS implementation was 2 out of 3158 or 0.06%, which increased after CDS implementation to 14 out of 4199 or 0.33%.

Additionally, the CDS tool should ensure significantly higher uptake of indicated immunizations, for the right patient populations, at the right time. Our findings are in keeping with previous studies which found significant increases in herpes zoster^[19] and influenza vaccine^[20] uptake after implementation of CDS systems. In theory, these effects should lead to improved outcomes, with less admissions, ER visits, outpatient appointments and sick days for adults with influenza, chest infections, meningitis and shingles, as well as other related diseases. Clearly, we would need further studies to illustrate these expected positive clinical outcomes.

Additionally, it is clear that the much-improved electronic documentation of chronic diseases will save the physician time and unnecessary effort searching through patient histories. This is another significant process of care outcome, and the increased awareness of patient problems should lead to a number of benefits, including more comprehensive, patient-centered care, safer practice, and more effective use of consultation time, generally improving efficiency and ultimately clinical outcomes.

The technology makes the diagnoses clear, so that the care provider is fully informed in a timely and concise manner. This means he might tailor his management to these chronic diseases more quickly, and these diagnoses would be at the forefront of his mind throughout the consultation. In terms of processes of care, most of our processes of care including adherence to colon, breast and cervical cancer screening tests as well as adult immunizations, have certainly improved through implementation of CDS systems. This is in keeping with the current literature,^[21] where CDS systems have been shown to significantly improve clinical practice i.e., processes of care, in the majority of trials.^[22,23]

Some studies have found that sites using electronic health records have been shown to achieve higher standards of care and better outcomes in diabetes management,^[24] but clinical benefits of electronic health records and clinical decision support tools have not been evident in the majority of studies.^[25-27] However, we have certainly found that implementing fully electronic patient health records and health maintenance CDS systems has not only led to expected process of care benefits, but has also improved a number of patient outcomes, including more frequent early diagnosis of breast and colorectal cancers. It has also improved the yield of our cancer screening programs. CDS systems however did not appear to have significant effects on patient outcomes in chronic disease management, despite improved electronic documentation and increases in the requesting of some investigations like LDL cholesterol, in accordance with latest guidelines.

One criticism of previous studies has been that sample size is too small and study duration too short to truly reveal clinical effects.^[28] It is clear that larger long-term cohort studies will certainly be required to assess whether the well understood improvement in processes of care with CDS systems will translate into the ultimate objective of improved clinical outcomes.

Key Points and Conclusions

- CDS systems implemented at KFH-FMC significantly increased uptake of indicated adult vaccinations and timely cancer screening tests.
- CDS systems implemented at KFH-FMC significantly improved patient care outcomes with regards to early diagnosis of breast and colon cancer due to proper implementation of screening programs.
- CDS implementation significantly increased the yield of Colorectal and breast cancer screening programs, making the screening programs more efficient and more effective probably due to the right patients receiving the indicated tests at the appropriate times.
- However, CDS systems at KFH-FMC did not have any significant effect on patient care outcomes in chronic disease management.
- Larger longer-term studies are required to understand whether CDS driven improvement in processes of care like the uptake of vaccines and screening tests will translate into significant improvement in long-term patient outcomes.

In conclusion, technology-assisted implementation of screening and vaccination programs, utilizing CDS, triggering reminders, and pop-ups, will lead to clear improvement in process of care outcomes, earlier detection of significant pathology, and likely improvement in a range of clinical outcomes which is the ultimate goal of value-based healthcare delivery. A team of healthcare professionals and healthcare informatics professionals working together in a collegial, collaborative manner and learning from each other, was essential to the success of this project.

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Conflicts of interest

There are no conflicts of interest.

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