

I-SCREEN: Increasing Screening for Cancer using a Randomized Evaluation of EHR-based Nudges

University of Pennsylvania

Dr. Amol Navathe

Dr. Shivan Mehta

Dr. Joshua Liao

NCT# 06177795

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1. Abstract

Cancer remains a leading cause of mortality among older adults in the United States. However, cancer screening is often underutilized despite established United States Preventive Services Task Force (USPSTF) guidelines supporting appropriate cancer screening to help prevent death and adverse cancer-related outcomes. Barriers to appropriate screening are even greater for groups that are at particularly high risk for screening non-completion. Key drivers of screening underutilization include decision-making biases facing clinicians and patients, highlighting the need for scalable solutions that are designed to address these biases and tailored to overcome barriers facing high-risk patients. Interventions designed using behavioral economic principles, such as nudges, improve behavior by modifying the choice environment to address biases that can lead to suboptimal decisions. In this study, we will evaluate personalized nudges to clinicians and patients to help increase breast cancer screening among older adults, with a particular emphasis on those at high risk for non-completion of cancer screening. In partnership with Penn Medicine (Philadelphia, PA) and Case Western Reserve University-University Hospitals (Cleveland, OH; [UH]), we will complete two complementary, concurrent 6-month, cluster randomized, pragmatic trials. We will then replicate our interventions at Lancaster General Health (Lancaster, PA).

2. Overall objectives

The objectives of the study are to:

- 1) To conduct a two-arm pragmatic cluster-randomized controlled trial to test the effectiveness of personalized electronic health record (EHR)-based nudges to clinicians and patients on increasing breast cancer screening rates.
- 2) To evaluate if EHR-based nudge interventions reduce disparities in breast cancer screening rates for high-risk subgroups.
- 3) To inform future design of tailored EHR interventions by examining heterogeneity of treatment response with respect to clinician and patient characteristics

3. Aims

3.1 Primary outcome

The primary outcome is screening mammogram completion within 3 months after the first eligible primary care visit.

3.2 Secondary outcome

The secondary outcome is screening mammogram completion within 6 months after the first eligible primary care visit.

4. Background

Cancer is a leading cause of mortality in the United States.¹ While strong USPSTF guideline recommendations support appropriate screening for early detection and to avoid preventable deaths, breast cancer screening is often underutilized.^{2,3} Increasing breast cancer screening rates is challenging, in part, because it requires complementary decisions from clinicians (e.g., recommend and counsel patients about screening) and patients

(e.g., to internalize risks and choose to complete screening). Presently, the lack of interventions directly targeting both clinicians' and patients' decision-making may underscore the relatively stagnant screening rates in the United States. There is a significant need to develop and scale low-cost interventions that increase breast cancer screening while simultaneously addressing the needs of high-risk patients and reducing disparities. Building upon our prior work, we propose to develop and test EHR- based clinician and patient nudges, with an additional intensified nudge to high-risk patients, to help increase screening mammography rates.

5. Study design

5.1 Design

This study consists of two complementary and concurrent, cluster-randomized, pragmatic trials to be conducted at Penn and UH:

Penn Trial

This study will evaluate the effectiveness of personalized nudges to clinicians and patients, relative to a control, to increase screening mammogram completion among older adults. This will include clinician and patient level nudge interventions, with an additional, intensification nudge for patients identified as high risk for not completing their screening mammogram.

This cluster-randomized trial will randomly assign primary care practices in a 2:1 ratio to either a nudge intervention or control arm using a covariate-constrained randomization.⁴ The intervention arm consists of a multi-component nudge intervention for patients and primary care clinicians. For clinicians within the intervention arm, a screening mammography order will be pended on the PCP's behalf prior to the primary care visit. This will shift the choice architecture to the default (from opt-in to opt-out), and it reduces effort by the clinician/care team to have to remember to order a mammogram for each eligible patient.^{6,7} The unsigned order will be visible to the clinician during the visit and they will maintain the option to sign or cancel the order.

All patients seen for a visit at the clinics who are randomized to the intervention arm will receive a text message at 4-and 14-days post-visit, sent via Way to Health, a HIPAA-compliant, approved platform. The text message delivered at 4-days post-visit will remind the patient that a screening mammogram was ordered for them by their doctor, that an appointment has been reserved for them (endowment framing), and to pre-commit to scheduling their mammogram. The 14-day text message will be sent to participants who have not scheduled their mammogram and will remind them that a mammogram was ordered and to schedule theirs today. Both text messages (4-and 14-days) will include a phone number to schedule and a link to the electronic patient portal for self-scheduling. Those patients who do not have a cell phone number listed in the EHR will receive automated voice recording (AVR). For the patient intensification nudge, we will use the results of our previous analyses at our study sites to identify patients at high risk for non-completion within the clinic intervention arm (**Medicare or Medicaid insurance, no active EHR patient portal account, or no log-in to patient portal in the prior year**). Patients who meet the established criteria for high risk will be randomized 1:1 to receive a series of additional text-based chat bot nudges or no additional nudge. We will translate patient text messages in Spanish for patients who require an interpreter according to their language preferences in the EHR. Figure 1 provides an overview of the study design.

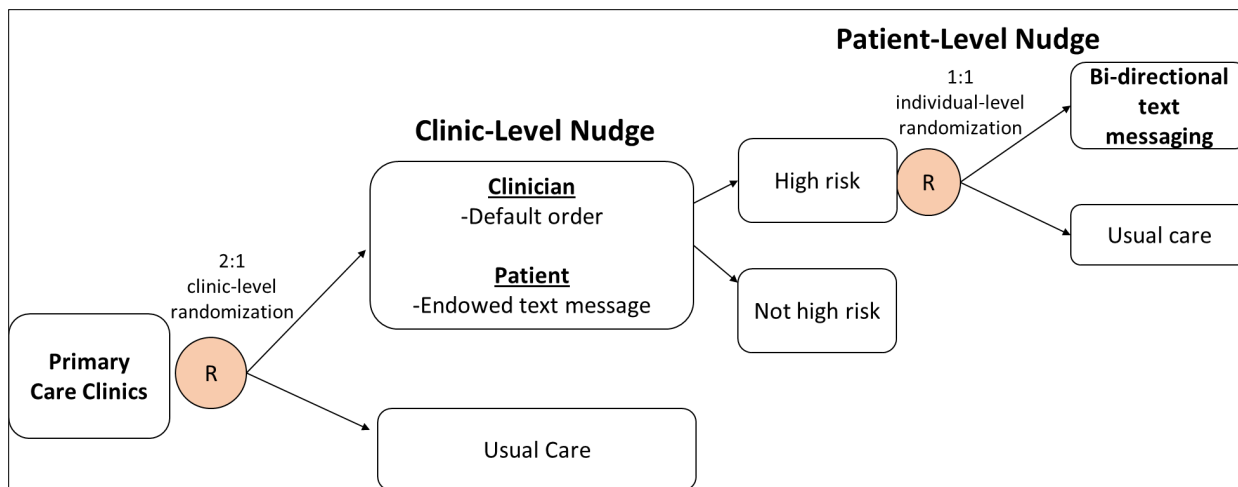


Figure 1. Overview of Penn Trial study design. R = randomization step

UH Trial

This study will be a cluster-randomized, pragmatic trial to evaluate the effectiveness of personalized nudges to clinicians, relative to a control, to increase screening mammogram completion among older adults.

This cluster-randomized trial will randomly assign primary care providers in a 1:1 ratio to either a nudge intervention or control arm using a covariate-constrained randomization.⁴ The intervention arm consists of a nudge intervention for primary care clinicians. For clinicians within the intervention arm, a screening mammography order will be pended on the PCP's behalf prior to the primary care visit. This will shift the choice architecture to the default (from opt-in to opt-out), and it reduces effort by the clinician/care team to have to remember to order a mammogram for each eligible patient.^{6,7} The unsigned order will be visible to the clinician during the visit and they will maintain the option to sign or cancel the order.

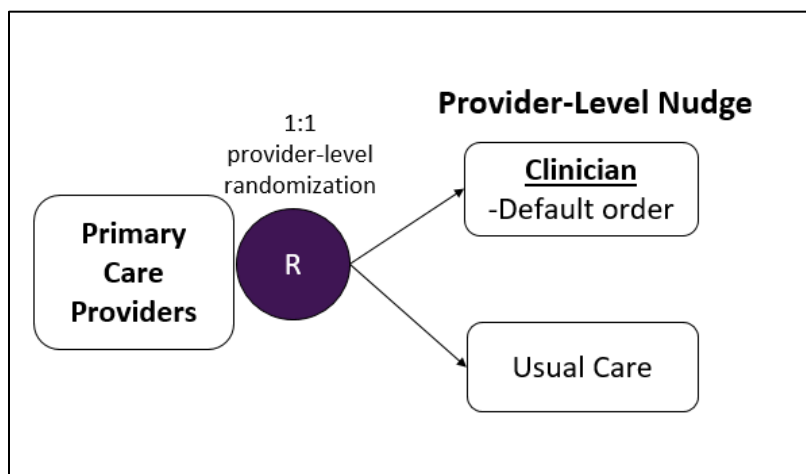


Figure 2. Overview of UH Trial study design. R=randomization step

5.2 Study sites

Penn Medicine and UH will be the primary sites for these trials, with Penn serving as the primary IRB site. Lancaster General Health is the study replication site.

5.3 Study duration

The study (including replication) is expected to take 3 years to complete including study preparation (year 1), trial intervention (year 2), replication (year 3), analysis, and dissemination (year 3). The study intervention will run for 6 months.

5.4 Resources necessary for human research participation

The research staff spans the Penn Medicine Center for Health Care Innovation and Department of Medical Ethics and Health Policy to ensure Investigator support. This staff includes a project director, a project manager, research coordinator, and data analysts. To ensure that all staff assisting with research are adequately informed about the protocol and research related duties, the team will meet regularly both internally and with external stakeholders, including all research staff at partner sites UH and Lancaster General Health, after which meeting minutes and task lists will be distributed. All members of the research team have completed CITI human subjects research training. Additionally, the protocol and related task sheets will be shared on a drive accessible to all staff members. The timeline has been constructed to allow for adequate time to conduct and complete the research. There are adequate facilities to ensure the research can proceed.

5.5 Target population

Patients between 40 and 74 years of age in primary care practices who have a scheduled new or return, non-urgent/sick in-person visit with a PCP during the intervention period and are eligible for a screening mammogram based on Health Maintenance data will be included in this study.

5.6 Subjects enrolled by Penn researchers

Based off our power calculations and preliminary data work, Penn Medicine is expected to enroll approximately 15,000 patients.

5.7 Subjects enrolled by collaborating researchers

Based off our power calculations and preliminary data work, UH is expected to enroll approximately 6,416 patients.

5.7 Accrual

Patients in this trial will accrue based on their eligible visit during the study period. An eligible visit is defined as the patient's first scheduled new or return non-urgent/sick visit at an eligible clinical site during the study window. Patients in all study groups at Penn Medicine will be enrolled in the trial 1 day before their scheduled eligible visit. Patients at UH will be enrolled between 1 and 3 days prior to their scheduled eligible visit.

5.8 Key inclusion criteria

Patient Inclusion Criteria

All patients must meet the following criteria to be eligible:

- 1) Women between 40 and 74 years of age

- 2) A scheduled new or return (non-urgent/sick) primary care visit at one of the study practices (Penn Trial) or with one of the study primary care providers (UH Trial)
- 3) Are overdue and eligible for a mammogram per Health Maintenance
- 4) Does not have a future scheduled mammogram appointment

For the Penn Trial patient intensification nudge, at least one of the following criteria must be met to be considered high risk and randomized to receive the intensification nudge:

- 1) Medicare Insurance
- 2) Medicaid Insurance
- 3) No EHR patient portal account
- 4) Zero log-ins to EHR patient portal in the previous year

Other high risk factors may be identified on a site by site basis.

5.6 Key exclusion criteria

Patients will be excluded from the study if:

- 1) History of bilateral mastectomy
- 2) Have a mammogram exclusion modifier in Health Maintenance
- 3) Have no phone number (home or mobile) listed in their chart (Penn Trial only)

6. Subject recruitment

Information on PCPs and their patients at Penn Medicine, UH, and Lancaster General Health will be obtained from the electronic health record using Clarity, an Epic reporting database.

7. Subject compensation

No compensation will be offered in this study.

8. Study procedures

8.1 Consent

Based on our project correspondence with the Institutional Review Board, a waiver of informed consent is requested and has been approved for this project. This is a low-risk study conducted in partnership with clinical operations, and it is not feasible to consent every patient and clinician for a project of this scope. Additionally, clinicians are being nudged towards an evidence-based standard of care within the three health systems for this project and based on the USPSTF evidence-based guidelines. Patients and clinicians are not being forced into completing a mammogram but, instead, this project is evaluating novel nudge interventions to help make it easier for clinicians and patients, especially those who are high risk, to deliver or receive evidence-based breast cancer screening. Patients and clinicians retain autonomy to not proceed with a screening mammogram for any given encounter.

8.2 Procedures

--Interventions--

Penn Trial

All patients in the intervention arm with a new or return, non-urgent/sick primary care appointment will be identified 1 day before their scheduled appointment.

The clinician nudge uses a default pended order for mammography that will be visible to the provider during the visit encounter. Clinical staff will have the option of signing the order or dismissing it if they deem it inappropriate for a given patient.

The standard patient nudge will be delivered by two text messages. All patients completing a primary care visit and whose provider signed the pended order will be identified and sent a text message at 4-and 14-days post-visit. The message delivered 4-days post-visit will remind the patient that a screening mammogram was recently ordered by their doctor, that appointments have been reserved for them, and to pre-commit to scheduling. The message delivered at 14-days post-visit will remind the patient of their recent screening mammogram order and encourage them to schedule their appointment, if one has not already been scheduled. Both messages will include a scheduling phone number and link to the electronic patient portal to assist with scheduling. Text messaging will not be sent if the patient's PCP dismisses the pended order at the visit.

Patients randomized to receive the high-risk intensification messaging will receive the same standard nudge and will also have the option to additionally engage with a bi-directional text message intervention after their visit that will query the patient about common questions or concerns about completing a screening mammogram. The bi-directional text messaging intervention will provide additional educational materials based on patient response as well as information about resources to help navigate to screening. As with the standard patient nudge, the high-risk intensification messaging will not be sent if the patient's PCP dismisses the pended order at the visit.

UH Trial

All patients in the intervention arm with a new or return, non-urgent/sick primary care appointment with an included PCP will be identified 1 to 3 days before their scheduled appointment.

The clinician nudge uses a default pended order for mammography that will be visible to the provider during the visit encounter. Clinical staff will have the option of signing the order or dismissing it if they deem it inappropriate for a given patient.

--Data--

Data on PCPs and their patients will be obtained from Clarity (Epic's data reporting database). Clinician data includes self-reported gender and type of medical degree. Patient information includes demographic information, information about comorbid conditions (including diabetes, hypertension, and chronic kidney disease, and comorbid conditions needed to calculate the Charlson Comorbidity Index), appointment data, contraindications for mammography, and mammogram completion.

--Randomization--

Penn Trial

Primary care practice level randomization will occur electronically. We will randomize clinics 2:1 to the nudge interventions or control arm using covariate-constrained randomization.⁴ Covariate-constrained randomization first enumerates a large number (e.g., 50,000) of possible intervention allocations. Then, a measure of covariate balance is computed with respect to a set of pre-specified covariates for each possible allocation. Finally, from a subset of possible allocations that achieve adequate covariate balance, one is randomly chosen as the final allocation of interventions for the study. We will implement a version of covariate-constrained randomization that balances the distribution of clinic size, baseline outcome rate, and panel risk across arms. At Penn, panel risk is defined as the number of patients with Medicare or Medicaid insurance, no active EHR patient portal account, or no login to patient portal in the prior year. The randomization procedure will be implemented in R.⁸ For the replication trial at Lancaster General Health, we will implement covariate-constrained randomization using the *cvcrand* package in R to balance the distribution of clinic size and panel risk across arms.

Within the high-risk patient subgroups, stratifying by intervention clinics, patients will be randomized 1:1 in Way to Health using permuted block randomization using random block sizes of 2, 4, and 6 to receive the additional intensification bidirectional text messaging nudge or standard messaging.

UH Trial

Primary care provider level randomization will occur electronically. We will randomize providers 1:1 to the nudge interventions or control arm using covariate-constrained randomization, as described above.⁴ We will implement a version of covariate-constrained randomization that balances the distribution of baseline outcome rate, panel risk, and panel size across arms. At UH, panel risk is defined as the number of patients with Medicare or Medicaid insurance. The randomization procedure will be implemented in R.⁸

9. Analysis plan

Prior to analyses, we will produce data summaries to assess data quality, data distribution, and randomization success. All analyses will be performed using an intention-to-treat approach. To ensure even comparison across practices/providers and arms, we will classify all eligible patients that are scheduled for a primary care visit as being enrolled in the study. Consistent with the intention-to-treat approach, patients who do not show up to the clinician visit will be considered enrolled and included in the primary analysis.

--Power Calculations--

Penn Trial

For the following power calculations, we used an adjusted Type I error of 0.025 to account for two comparisons: 1) clinic-level nudges versus usual care, and 2) intensification for high-risk patients versus no intensification within practices where clinic-level nudges are provided. Based on retrospective data from our health system, we will have 90% power to detect a 9-percentage point difference in the screening completion rate for comparison #1. This calculation was based on Penn data alone, assuming 2:1 randomization of N=30 participating clinics, an average cluster size of n=510 patients, an intraclass correlation (ICC) of 0.02, and a 20% completion rate in the control arm. For comparison #2, we will have over 90% power to detect a 3-percentage point difference if the rate of screening amongst high-risk patients who receive standard text messaging is 20%, i.e., reflecting an assumed 11% completion rate amongst high-risk patients not exposed to any intervention and an assumed 9-percentage point effect of default ordering and standard text messaging

combined. This calculation assumed 1:1 individual-level randomization of n=260 high-risk patients within each of N=20 clinics that will be randomized to receive clinic-level nudges. These power calculations used Penn data only to estimate the average number of patients per clinic and the number of high-risk patients who will be randomized.

UH Trial

Based on retrospective data from UH, we will have over 90% power to detect a 6-percentage point difference in the screening completion rate between the nudge and control arms. This calculation was based on UH data alone, assuming 1:1 randomization of N=82 participating providers, an average cluster size of n=80 patients per provider, an intraclass correlation (ICC) of 0.02, and Type I error of 0.05.

--Analysis--

The Penn and UH trials will be analyzed separately. The primary analysis will fit generalized estimating equations (GEE) with a binary outcome indicating mammogram completion within 3 months of a PCP visit (primary). We will also perform analyses based on a binary outcome that indicates mammogram completion within 6 months of a PCP visit (secondary).

Investigators and analysts will be blinded to study arm assignment during the intervention and analysis phases. The statistician is responsible for clinic- (Penn) and provider- (UH) level randomization, but subsequently will be blinded to study arm assignment for the remainder of the intervention phase and analysis phase. Project staff (site PIs, project director, project manager, and study coordinators) will be unblinded during the intervention and analysis phases to complete daily study activities and prepare the blinded analysis files. Unblinding for investigators, statisticians, and analysts will be completed by the project staff and occur at the end of study analysis once all of the outcomes have been ascertained.

Penn Trial

For analysis of the Penn trial data, an exchangeable working correlation will be specified at the clinic level for comparison #1 and robust standard errors will be provided, clustered at the clinic level. An independence working correlation and robust standard errors without clustering will be used for comparison #2. For the primary analysis, we will include a patient-level indicator of whether the patient had a prior mammogram order within the last 6 months before their eligible visit as the key variable of interest. In sensitivity analyses, we will explore alternative specifications for the working correlation structure to examine robustness of parameter estimates and inference.

We will examine effects of the interventions on overall rates of ordering. Using Penn trial data, we will compare rates of ordering between the three intervention arms: 1) control, 2) clinic-level nudges only, and 3) clinic-level nudges with intensification for high risk. We will fit a GEE with binary outcome indicating whether a pending order was signed or not. We will fit the model using the weighted and replicated approach⁹ to account for the fact that low-risk patients seen in the clinics that received nudges are consistent with both intervention arms 2) and 3). We will include terms for the main effects of clinic-level and individual-level nudges as well as their interaction. We will test the appropriate linear combinations of the parameters that correspond to pairwise differences between each of the three intervention arms. An independence working correlation with robust

standard errors will be used to account for uncertainty in the weight distribution due to variability in the empirical proportion of high- versus low-risk patients. Using UH trial data, we will compare rates of ordering between the control and provider-level nudges arm using a GEE with binary outcome and robust standard errors clustered at the provider level using an exchangeable working correlation.

In models for estimating the effect of the clinic-level nudges (Penn trial), we will account for the clinic-level covariate-constrained randomization by including clinic size and panel risk as covariates. In models for estimating the effect of intensification on high-risk patients (Penn trial), we will control for differences across health system by including clinic fixed effects (each clinic site will be health system specific so will account for health system as well), which will also account for the stratified randomization of individuals within clinic.

For the Penn trial, we will perform exploratory subgroup analyses by risk group as it is defined for the individual randomization. First, this will allow us to study the effect of the clinic-level nudges versus usual care among non-high-risk patients. For the high-risk strata, we will fit models that include each category used to define high risk (e.g., Medicare, Medicaid, no log-in to patient portal in previous year) as well as their interaction with treatment arm to determine which high-risk subgroups experienced the greatest benefits of the clinic- and individual-level nudges. We will also include visit-level analysis with clustering by patient as an exploratory analysis.

UH Trial

For analysis of the UH trial data, an exchangeable working correlation will be specified at the provider level and robust standard errors will be provided, clustered at the provider level. For the primary analysis, we will include a patient-level indicator of whether the patient had a prior mammogram order within the last 6 months before their eligible visit as the key variable of interest. In sensitivity analyses, we will explore alternative specifications for the working correlation structure in each model to examine robustness of parameter estimates and inference.

We will examine effects of the interventions on overall rates of ordering. Using UH trial data, we will compare rates of ordering between the control and provider-level nudges arm using a GEE with binary outcome and robust standard errors clustered at the provider level using an exchangeable working correlation.

In models for estimating the effect of provider-level nudges (UH trial), we will account for the provider-level covariate-constrained randomization by including the rate of the outcome in the provider's panel over the previous year and panel risk as covariates.

For the UH trial, we will perform exploratory analyses to test whether the effects of the provider-level nudges are modified by the proportion of a provider's panel at high risk. This will involve fitting a GEE model with treatment arm, panel risk measured at the provider level (i.e., proportion of panel at high risk), and their interaction. We will also include previous year outcome rates in the model to account for the constrained randomization.

10. Investigators

Amol Navathe, MD, PhD is a Principal Investigator and Associate Director of the Center for Health Incentives and Behavioral Economics and Professor of Medicine, and Health Policy at the University of Pennsylvania. He is a general internist and health economist with a research portfolio focusing on physician behavior. His expertise includes large-scale policy trial design in multiple health plans and health care organizations around physician incentives and high-value practice.

Shivan Mehta, MD, MBA, MSHP is a Principal Investigator and an Associate Professor of Medicine and Health Policy at the University of Pennsylvania. He has prior experience leading clinical trials to deploy interventions that leverage behavioral economics and technology to improve population health outcomes.

Joshua Liao, MD, MSc, FACP is a Principal Investigator and Professor and Division Chief of the William T. and Gay F. Solomon Division of General Internal Medicine at University of Texas Southwestern Medical Center. He has prior experience designing and implementing nudge interventions in pragmatic randomized trials aimed at improving health care value and population health.

Peter Pronovost, MD, PhD is a Principal Investigator, and the Chief Clinical Transformation Officer and Professor of Medicine at University Hospitals and Case Western Reserve University, respectively, in Ohio. He will contribute clinical and research expertise, experience with executive leadership for clinical transformation, and experience with large-scale implementation science.

Kristin Linn, PhD is a Co-Investigator and an Assistant Professor of Biostatistics at the University of Pennsylvania. She has prior expertise in statistical methods for sequentially randomized clinical trials, predictive modeling, and machine learning techniques.

Kimberly Waddell, PhD, MSCI is a Co-Investigator and an Assistant Professor of Physical Medicine and Rehabilitation at the University of Pennsylvania and a Core Investigator at the Philadelphia VA Center for Health Equity Research and Promotion. She has prior experience with clinical trials and nudge interventions to improve clinician and patient decision-making.

11. Human research protection

11.1 Data confidentiality

Computer-based files will only be made available to personnel involved in the study through the use of access privileges and passwords. Wherever feasible, identifiers will be removed from study-related information. Precautions are already in place to ensure the data are secure by using passwords and HIPAA-compliant encryption.

11.2 Subject confidentiality

Data on clinicians and patients will be obtained from Epic. Any information that is obtained will be used for research purposes only. Information on patients will only be disclosed within the study team and to the patient's PCP. All study staff will be reminded of the confidential nature of the data collected and contained in these databases.

Information about study subjects will be kept confidential and managed according to the requirements of the Health Insurance Portability and Accountability Act of 1996 (HIPAA). No source documents will be printed or maintained in paper form at the study sites. Operational data used for daily study management will be

stored on a secure drive maintained behind the University of Pennsylvania Health System (UPHS) firewall. Analytic data will be stored within Penn Leonard David Institute's Health Services Research Data Center (HSRDC). HSRDC is maintained at a high-security level in accordance with federal regulations governing secure computer systems (e.g., the Federal Information Security Management Act-FISMA). The Way to Health (W2H) platform servers are based in the University of Pennsylvania Digital Academic Research Transformation (DART). The DART provides a secure computing environment for a large volume of highly sensitive data. DART requires all users of data or applications on DART servers to complete a DART-hosted cybersecurity awareness course annually, which stresses federal data security policies under data use agreements with the university. Curriculum includes HIPAA training and covers secure data transfer, passwords, computer security habits and knowledge of what constitutes misuse or inappropriate use of the server. W2H uses a role-based access control (RBAC) approach to assure that participant confidentiality and study integrity is preserved. Access is granted by invitation only and can be revoked at any time. The W2H Team are employees of the University of Pennsylvania and Penn Medicine. All W2H team members have completed HIPAA Security training and CITI Protection of Human Subjects Research Training - ORA. Access to the backend database is restricted and only available to a select group of developers. The database is accessible only via a secure VPN (Virtual Private Network) and cannot be accessed from the public internet at all, i.e. authorized users can only access the databases from within Penn's network and over a secure VPN channel. Data from participating sites will be transferred to Penn (the data coordinating center) according to the methods defined in a fully executed Data Use Agreement. All data will be covered under the appropriate Data Use Agreements between Penn Medicine, University Hospitals, and Lancaster General Health and follow strict security guidelines.

11.3 Subject privacy

All efforts will be made by study staff to ensure subject privacy. Data will be evaluated in a de-identified manner whenever possible.

11.4 Data disclosure

Information on patients will only be disclosed within the study team and to the patient's primary care clinician (to whom this information is already available).

11.5 Protected Health Information/Data Protection

- Name
- Street address, city, county, precinct, zip code, and equivalent geocodes
- All elements of dates (except year) for dates directly related to an individual and all ages over 89
- Telephone and fax numbers
- Medical record numbers

11.6 Data and safety monitoring

A Data and Safety Monitoring Board (DSMB) is an independent group of experts convened to protect the safety of research subjects and to ensure that the scientific goals for the project are being met. While this study presents very low risk, the DSMB will be appointed by and act in an advisory capacity to the National Institute on Aging (NIA) to monitor participant safety, data quality and to evaluate the progress of the study. The Data and Safety Monitoring Plan (DSMP) will be reviewed and approved by the DSMB prior to study start. Detailed

information about safety monitoring and reporting can be found in the Manual of Operating Procedures (Section 11) and the Data and Safety Monitoring Plan.

11.7 Risk/benefit

11.7.1 Potential study risks

There are minimal risks to PCPs and patients in this trial. Following established guidelines (USPSTF) and ordering a mammogram is a standard of care for these patients. The only research-related activity is the randomization of participants to different behavioral nudge strategies to increase mammography completion rates. Potential risks include patient frustration with messaging or outreach or duplicate mammography completion within the recommended interval. Risks will be minimized by excluding any patients for which this study is not appropriate, i.e. patients with history of mastectomy, or patients who are up to date on breast cancer screening.

There is a risk of breach of data and confidentiality. To minimize the risk of breach of data and confidentiality, we will use secure, encrypted servers to host the data and conduct the analysis. Operational data used for daily study management will be stored on a secure drive maintained behind the University of Pennsylvania Health System (UPHS) firewall. Analytic data will be stored within Penn Leonard David Institute's Health Services Research Data Center (HSRDC). HSRDC is maintained at a high-security level in accordance with federal regulations governing secure computer systems (e.g., the Federal Information Security Management Act-FISMA). The Way to Health (W2H) platform servers are based in the University of Pennsylvania Digital Academic Research Transformation (DART). Data from participating sites will be transferred to Penn (the data coordinating center) according to the methods defined in a fully executed Data Use Agreement. All data will be covered under the appropriate Data Use Agreements between Penn Medicine, University Hospitals, and Lancaster General Health and follow strict security guidelines.

11.7.2 Potential study benefits

Receiving a biennial mammogram is important for early detection of breast cancer and the overall health of patients. The EHR could be utilized to identify eligible patients, and patients at high risk for not completing their mammogram, and deliver nudges to help improve completion rates. The knowledge gained on how to increase mammography completion rates could be applied to other populations and implemented at other health systems. PCPs may benefit from receiving feedback on their performance and having the mammography order automatically ordered to help streamline the ordering process and prevent extra burden.

11.7.3 Risk/benefit assessment

The risk/benefit ratio is highly favorable given the potential benefit from eligible patients receiving a mammogram, especially those identified as high risk, that ordering and receiving a biennial mammogram is within the standards of care in a primary care practice, and that efforts have been put into place to minimize the risk of breach of data.

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