PSRS / My Wellness Portal / DartScreen:
A Health IT Framework for Prospective Care Delivery in Primary Care

The Preventive Services Reminder System (PSRS) / patient "My Wellness Portal" / DartScreen web-based application is one of the most sophisticated and effective prospective care management tools in current practice. It is an open-source, comprehensive clinical application for improving the delivery of individualized preventive services via patient registry, prompt/reminder, clinical decision support, care coordination, health risk appraisal (HRA) and personal health record (PHR) functions that are accessible through secure practice and patient web portals. It has been developed and maintained by the Department of Family and Preventive Medicine (DFPM) at the University of Oklahoma Health Sciences Center (OUHSC) since 2002.

The PSRS / Wellness Portal / DartScreen system has been designed from the bottom-up with constant input from front-line primary care practices, clinicians, nurses, and other providers in Oklahoma and nationwide. The PSRS platform supports several applications, including the ones listed in the title, but they all use the same technological and security architecture. PSRS is a proven technology that successfully incorporated system components that support effective preventive care and health management programs.

1) Patient Registry & Tracking. An industrial-strength PostgreSQL relational database currently tracks 19 patient demographic identifiers, 43 individual immunization parameters, 59 preventive interventions (e.g. screening tests, counseling sessions, etc), over 200 personal risk factors (including chronic illnesses), allergies and adverse reactions, and patient care preferences for over 500,000 patients. The patient search engine and on-demand database auditing capabilities provide a variety of ways for users to interact with health information effectively and securely.

2) Prompt/Reminder & Clinical Decision Support. The strength of PSRS is the sophisticated and unique prompt/reminder and decision support algorithm designed in a thoughtful architecture that distinguishes PSRS from generic tools that often provide an indiscriminate number of prompts to users based only on age, gender, and some disease specific information. A unique recommendation algorithm considers all information available in the patient registry and evidence-based preventive services guidelines (from the USPSTF, ACIP/CDC, and AAFP) to generate a list of preventive services indicated for a patient on any date in the past, present, or future. Set theory is used to fit patients who are behind on immunizations into the most appropriate catch-up regimen. Recommendations are generated by an internal secure web service that receives a simple coded request from the client including age, gender, recommendation date, past service history, personal risk and preference profile and responds with a structured text stream of preventive recommendations that are parsed by the web server and sent back to the client's browser securely. The recommendations are available to clinicians and patient users online or via a printable PDF document that summarizes history of past services, current recommendations and patient risk factors. Based on substantial experience and expertise in health care delivery research and health information technology, the developers provided excellent balance between the granularity and clinical importance (impact) of prompts in PSRS that significantly increased the utility and adoption of the system among health care providers. Since most chronic diseases require a systematic care management approach in primary care, PSRS has the advantage of a built-in longitudinal care management approach and the vision of prospective care and overall wellness.

3) Repository of Patient Resources. PSRS provides a significant body of patient education resources in an interactive environment. When providers are prompted for certain services that are due for the patient, PSRS prepares and optionally prints a personalized packet of educational materials either in English or in Spanish based on the client's preference. PSRS also incorporates a library of CDC and AAFP –approved educational materials on 21 distinct vaccination types, 20 secondary preventive

interventions (including consultations for unhealthy behaviors), EPSDT (well child) examination forms for all age-groups, and disease-specific handouts. In addition, PSRS can also provide a framework for delivering point-of-care information on community resources available for patients in their area based on health conditions or specific patient needs.

4) Digital Document Management System: A digital document management system has also been incorporated that can receive, index, store, and retrieve document files using a relational database (in a binary format), and further process, store, populate, and exchange structured, searchable information extracted from these documents. The Digital Document Management System provides an advanced platform to support rapid and database-driven information capture and exchange.

5) Patient Wellness Portal. PSRS is strategically integrated into an optional, but comprehensive health IT architecture that includes a connected patient Wellness Portal. The Portal empowers patient users to interact securely with their PSRS records over the Internet and also utilize additional features that help them track, populate, evaluate, and respond to personalized and prioritized preventive care recommendations. They can also receive education about preventive measures, communicate securely with their PCP's office (secure messaging), and maintain their personal health records (PHRs) via the Portal.

6) Personal Wellness Record. With a click of a button, the Wellness Portal can generate an ASTM - standard Continuity of Care Record (CCR) or ASTM-HL7 compliant Continuity of Care Document (CCD) for patients and providers that include the complete patient "chart" in a portable and easily reviewable XML format. Based on Meaningful Use criteria, all certified Electronic Health Records (EHRs) are capable of importing and exporting patient information in a CCR or CCD format.

7) Health Risk Appraisal (HRA). A comprehensive, web-based HRA instrument has been designed and incorporated into the Wellness Portal. The advanced HRA explores over 200 potential risk factors in 13 health and wellness domains (including behavioral and psychosocial determinants of health) in about 20 minutes using a web-enabled device. Risk information is processed online by a novel risk engine that has been tested and validated in clinical studies. Based on the granular HRA input, evidence-based guidelines, patient preferences, and personal constraints, the engine calculates the projected health impact of each recommended and personalized preventive intervention and prioritizes them according to decreasing impact on length of life also quality of life (using estimated life expectancy and health expectancy). A detailed patient and clinician HRA Report is generated that provides global health measures, including estimated life expectancy, health expectancy, RealAge, and Wellness Score, in addition to a tailored "strengths and weaknesses" report, a prioritized list of possible interventions with calculated impacts on outcomes (visual scales), and populated suggestions for strategies and resources that can be used to act upon recommendations. The report is implemented in a patient-centered primary care context where the patient is a member of the care team. Ideally, a wellness nurse or health coach is also assigned to the patient from the practice who ensures that the agreed upon personal wellness plan is carried out systematically.

Additional Resources and PSRS Functions

- Patient Recalls: PSRS includes an electronic chart auditing and patient recall tool that helps clinicians track their performance and identify/recall eligible patients for preventive services. A list of patients who are due for services is produced by running each patient's profile through the recommendation algorithm and comparing service history with evidence-based, personalized recommendations in a selected patient group.
- Wellness Plan: A three-year prospective wellness plan can be generated for individual patients based upon the assumption that patients and clinicians address all items on the sequential recommendation lists each year. This Plan can become the cornerstone of prospective care

delivery and measurement of individualized quality of care (adherence to the personalized and agreed-upon wellness plan).

- Task Manager: The negotiated wellness plan can be recorded and tracked by a task management tool built into PSRS to streamline care delivery and personalize future recommendations.
- Health Information Exchange (HIE) Integration. PSRS has been interfaced with two HIE networks in Oklahoma using that exchange, parse and analyze CCD records aggregated from a variety of sources at the state-level. A demonstration study has shown the clinical potential of using the PSRS risk engine at the state-level to create an HIE with intelligence (HIE-*i*).
- Pediatric Screener Applications (DartScreen): PSRS also incorporates a set of comprehensive pediatric screeners that allow clinicians to complete rapid, 360 child health assessments, receive scored and color-coded risk reports and focus on evidence-based and high-impact interventions prioritized for the child based on the report.

PSRS was developed with financial support from the Oklahoma Health Care Authority (Oklahoma's Medicaid Program) and the Agency for Healthcare Research and Quality (AHRQ). Extensive input has been provided by community primary care clinicians, members of the Oklahoma Physicians Resource/Research Network (OKPRN). More information on PSRS / My Wellness Portal / DartScreen and screen shots of the web interfaces are available at http://www.okprn.org/health-it. The PSRS approach opens the possibility for addressing virtually all major health conditions in a patient-centered and goal-driven care delivery framework.

Compliance of the PSRS/Wellness Portal/DartScreen with Health Information Portability and Accountability Act (HIPAA) Privacy and Security Requirements

Protected health information (PHI) in PSRS is safeguarded by robust physical, hardware, software, and personal security measures that are in place in the health IT architecture. These measures cover all potential security areas, including identification/authentication, authorization, data access/connection, data transfer, data storage, hardware/server access, and operations logging/auditing. In detail:

- Identification/authentication: each individual user has a distinct and unique user name and a strong password that they must use to gain access to the PSRS/WP/DS web interface;
- Authorization: each provider site has a pair of industry-standard electronic security certificates (root certificate and personal certificate) installed in their computer browser's certificate store that identifies clinic sites and allows clinic users to access the PSRS website. Computers without client certificates installed on them are not able to access the secure practice portal. Clinician user certificates are installed individually at provider sites and not released (not available to the public). An automated annual client certificate renewal mechanism is in place for those who are already authenticated users of PSRS.
- Access/connection and data transfer: PSRS web servers run Apache Tomcat Standalone in a Java Struts environment and utilize state-of-the-art 128 bit strong encryption (HTTPS) technology and connections through the Secure Socket Layer (SSL) to connect clients and to secure connections and sensitive data transmitted via the Internet. Unique session identifiers are randomly assigned and encrypted at the beginning of each session to prevent session hijacking and man-in-the-middle attacks. All incoming packets pass through a single secure port (443) that is mapped to services internally.
- Data storage: Patient databases are completely separated from the presentation layer and the application layer (web server) using standard approaches that include full separation of authentication, authorization, and access supported by SUSE Linux Enterprise Server 10. No user other than the low-level internal database user has access to the main PostgreSQL database. A multiple level authentication of the database user is strongly enforced and exclusively server-side

application action classes are permitted to make connections to the database locally. Measures against SQL injection attacks are also in place.

- Hardware/server access: PSRS servers are heavily protected from unauthorized access and stored in a facility approved for housing sensitive personal health information (PHI) at the OUHSC Data Center. Physical security measures include a state-of-the-art server facility locked with multiple reinforced doors, high capacity and constant air-conditioning, a facility-wide automatic Halide fire extinguishing system, and locked cabinets within the server room to separate PSRS servers from other equipment. The PSRS database is backed up regularly in an immediate data recovery format and backups are stored at another secure location off site. Only the system administrator and OUHSC Data Center personnel have physical access to the server and backups.
- Logging/auditing: According to HIPAA regulations, the web server logs user operations extensively. Logs provide searchable information on: who accessed (or tried to access) the web server and when, which patient records were opened, what part of the patient record was reviewed and how many times, what information was entered or updated, whether recommendations were generated and data was downloaded for printing, what additional functions were utilized (e.g. running patient reports), and how much time the user spent online in a session. In addition, server logs also contain information on possible server component or power failure, scheduled down-time, and maintenance activities. Server logs are easily and securely accessible by the system administrator and backed up regularly for retrospective analysis or ongoing system audits.

Effectiveness of PSRS in Primary Care Practices

OUHSC DFPM researchers examined the clinical effectiveness and cost of implementation and maintenance of PSRS in two separate quasi-experimental studies. These effectiveness studies demonstrated that implementation of PSRS resulted in a remarkable improvement in the management, documentation, and delivery of prospective care in primary care practices. (Nagykaldi Z, Mold JW. The Role of Health Information Technology In The Translation of Research Into Practice, J Am Board Fam Med, 2007 Mar-Apr;20(2):188-95) The cost of implementation and maintenance of PSRS was determined via time-motion studies. These studies indicated that the use of PSRS costs about $2.15 – $3.50 per patient encounter in a typical primary care practice.

In two separate quasi-experimental studies (deliberately matched intervention and control practices), we examined the clinical effectiveness and cost of PSRS. Both studies were supported by the Oklahoma Healthcare Authority (Oklahoma's Medicaid Program). The first study included 2-3 years old patients and patients over 50 years of age with type 2 diabetes from six primary care practices. Apart from pneumococcal immunizations, PSRS significantly increased the rate of several routine childhood vaccinations in intervention practices compared to controls. The rate of adult pneumococcal vaccination, documentation of smoking status, and smoking counseling were also significantly improved in PSRS practices. The results are shown below in Table I.

PSRS Study #1

2-3 year olds	Control	PSRS	p-value
DTaP#4:	53%	86%	0.001
HepB#3:	61%	93%	0.0005
Pneumo:	27%	38%	NS
MMR#1:	61%	93%	0.0005

Adult Diabetics	Control	PSRS	p-value
Smoking status:	70%	93%	0.02
Smoking counseling:	13%	78%	0.0004
Pneumovax:	33%	78%	0.0003

The second controlled before-after study included Medicaid-insured patients in twelve different practices. PSRS was implemented in six control and six intervention practices for six months. Rates of routine childhood and adult immunizations, well child visits, and adult secondary preventive services were measured before and after the intervention. Study results and estimated p-values are shown in Table II.

PSRS Study #2

2-3 year olds - PRE/POST SERVICE COVERAGE

	HEPB#3	DTaP#4	IPV#3	HIB#4	MMR#1	PCV#3	EPSDT (24 MO)
INTERV. (PRE)	48%	28%	48%	29%	47%	19%	27%
INTERV. (POST)	78%	70%	80%	53%	73%	28%	38%
p(intervention; n=6)	**0.012**	**0.003**	**0.019**	**0.011**	**0.021**	0.113	**0.055**
CONTROL (PRE)	75%	69%	75%	51%	77%	29%	33%
CONTROL (POST)	71%	65%	71%	55%	75%	43%	30%
p(control; n=6)	0.631	0.367	0.446	0.377	0.629	0.190	0.271

52-74 year olds - PRE/POST SERVICE COVERAGE

	Adult dT	Adult Pneumo	Flu shot	Smk status	Smk counsel.	Mammo	Colon cancer screening
INTERV. (PRE)	15%	21%	30%	61%	29%	23%	16%
INTERV. (POST)	19%	27%	30%	74%	78%	55%	27%
p(intervention; (n=6)	0.190	**0.051**	0.303	0.141	**0.026**	**0.010**	**0.058**
CONTROL (PRE)	22%	38%	49%	82%	80%	42%	25%
CONTROL (POST)	23%	35%	34%	72%	71%	35%	19%
p(control; n=5)	0.805	0.707	0.208	0.460	0.356	0.536	0.864

PSRS significantly improved the rate of delivery of 10 out of 14 preventive services. The six-month implementation of PSRS did not improve the rates for the third dose of childhood pneumococcal vaccination, some adult vaccinations, including flu shots (measured during the spring and summer), and adult dT vaccinations. PSRS currently includes 40 distinct doses of childhood immunizations, well child visit recommendations, three adult immunizations, and 43 secondary and tertiary preventive services.

Feasibility and Acceptability of the Wellness Portal Implementation in Primary Care Practices

In the context of a randomized controlled trial, we developed a patient Wellness Portal that was linked to PSRS in eight OKPRN practices. Development of a prototype version of the Portal was accomplished through a systematic design process. We assembled an advisory committee of patients, clinicians, and practice staff to identify features and the structure of the Portal that would be the most generalizable. The

committee consisted of three OKPRN clinicians representing academic, private, and community practices who had HIT experience, nurses or medical assistants, two adult caretakers of pediatric patients, and two adult patients over the age of 50 with ongoing medical conditions. The committee met three times to discuss the Portal design. Provider and patient input were systematically catalogued and a list of elements recommended for portal inclusion was compiled. The Delphi Technique was employed as a means to achieve consensus on the final structure of the Wellness Portal. On a five-point Likert scale, members of the Advisory Committee ranked each element using the following criteria: 1) Ease of use; 2) Ease of understanding; 3) Optimal structure and content; 4) Perception of relevance to patients; 5) Appropriateness and usefulness of information; 6) Value of the service; and 7) Perception of potential impact.

The committee suggested that the prototype Portal should include the following features: patient demographic information; history of past preventive services, personal risk factors (e.g., allergies, adverse reactions, chronic conditions, and clinical / behavioral factors); symptoms tracking; health education materials; medication lists; linkage to childhood vaccination records; secure messaging with practices; appointment tracking and documentation of visits; screening and laboratory tests; and personal care preferences. The above parameters are fed into a sophisticated recommendation algorithm that delivers a set of evidence-based preventive service recommendations tailored to particular patients and their needs. Features such as daily tracking of blood pressure or weight, automatic BMI calculation, and tracking of blood glucose or lipid values can be used to record and visualize trends in graphical form over time.

Based on feedback from the committee, OKPRN clinicians, beta-tester patients, and national exemplars, who implemented patient portals, the development of the prototype was completed in five months. We conducted a field test to refine the integrated Wellness Portal over a six-month period in two OKPRN practices. Using a list generated from the practices' billing records, we identified 64 patients who were seen in the clinic during the previous three months. A screener questionnaire was administered to apply our exclusion criteria (e.g., language, computer access, and technical ability). The final sample included 30 patients.

Participant age ranged from 23-83 (mean=41). About 78% were female and 80% had some college education. The sample included 22.2% ethnic minorities; 18.5% were African Americans and 3.7% were Native Americans. Approximately 82% of the participants had some college education or more.

The majority of the patients found the Portal easy to use in terms of navigation (93.3%), finding information (90.0%), comprehension (93.3%), and instructions (93.3%). About 76.7% considered the information on the Portal to be arranged well. Between 60-86% of the patients regarded the Portal as a valuable resource, or a tool that provides important information (86.7%), improves patient-provider interactions (60.0%), and serves as a tool to facilitate participation in one's own care (80.0%) and decision-making (73.3%). In assessing overall impact, patients reported that the information in the Portal met their needs for wellness management (80.0%) and it was helpful for improving health (73.3%). Overall, the Portal was perceived as helpful to improve individual health (60.0%) and 70% believed the Portal will help them maintain their health and well-being.

Results of the My Wellness Portal Randomized Controlled Trial

We conducted a cluster randomized controlled trial (c-RCT) that included 422 adults 40 to 75 years of age and the parents of 116 children 2 to 5 years of age. Seventy three percent of patients used the Portal during the study. Both patient activation (measured via the PAM-13 questionnaire) and participants' perception of patient-centeredness of care (measured via the CAHPS instrument) increased significantly in the Portal group compared to control ($p=0.0014$ and $p=0.037$ respectively). A greater proportion of Portal users received all recommended preventive services (84.4% intervention vs. 67.6% control; $p<0.0001$), took low-dose aspirin, when indicated (78.6% intervention vs. 52.3% control; $p<0.0001$), received pneumovax because of chronic health conditions

(82.5% vs. 53.9%; p<0.0001) and age (86.3% vs. 44.6%; p<0.0001), despite having fewer visits over the study period compared to those in the control group (average of 2.9 vs. 4.3 visits; p<0.0001). Children in the intervention group received 95.5% of all recommended immunizations compared to 87.2% in the control group (p=0.044). A set of multivariate hierarchical linear analyses suggested that Portal use had a significant impact on patients' perception of receiving more patient-centered care (OR=1.80) and that system-level enhancements are likely to improve the clinician's knowledge about the medical history of their patients (OR=1.72). We concluded that a comprehensive patient portal that incorporates measures to improve behavioral health can increase patient-centeredness of care, improve patient activation, enhance the delivery of both age and risk factor appropriate preventive services, and promote the utilization of web-based personal health records.

Design of the Wellness Portal Health Risk Appraisal Tool

Led by Dr. Nagykaldi, our research team has developed a novel HRA instrument and risk engine and embedded it into the Wellness Portal. The development process followed a similarly systematic and user-centered approach to determine the features and content of the HRA tool and the method of web-based presentation. We first collected and analyzed a dozen existing HRA tools in current use (commercial, academic, privately developed, or in development) and interviewed seven national vendors that design and maintain HRAs. Then we consulted with clinician experts and key informants about their experiences with HRA tools and lessons learned from their implementations. Finally, we conducted in-depth (1-2 hours) "think-out-loud" interviews with a convenience sample of eight patients representing a range of age groups, both genders, and a variety of life situations. Patient testers provided rich and meaningful feedback about the content and presentation of the HRA tool, their understanding of HRA questions and answer options, and the value of feedback they received from the HRA report that helped us improve the instrument. The HRA risk engine takes its baseline information from National Center for Health Statistics (NCHS) population life tables for the 15 leading causes of death for all ages (0-110 years), both genders, and several races/ethnicities (White, African American, Hispanic/Latino, Native American, and Asian/Pacific Islander). Age, gender, and race-specific probability of death (q_d) values are used in a standard life-table calculation procedure to provide a *baseline* life expectancy (LE) estimate. The baseline estimate is the life expectancy of an "average" person in an age, gender, and ethnicity group.

To calculate an individualized LE estimate, baseline probabilities of death (q_d values) are converted into cumulative hazard (λ) values assuming an exponential survival distribution for each year ($\Sigma\lambda = - \ln (1 - P\text{death}[t])$. Lambda values are then distributed among the 15 leading causes of death (and all other causes as a sixteenth cause) according to the naturally occurring distribution ratios of deaths as indicated by NCHS life tables. A list of the most significant modifiable and unmodifiable risk factors for each cause of death has been carefully selected by an expert physician panel via evidence-driven consensus. The HRA tool asks specifically about these risk factors. Consequently, using relative risk (RR) values available from meta-analyses and large, representative epidemiological studies, the sixteen lambda values are adjusted according to individual risk factors and personal preferences gleaned from the HRA. Finally, adjusted lambda values are summed for each year (sum lambda or sum hazard) and corresponding probability of death values for each year of life are calculated. These personalized probabilities of death are then used in a second life-table calculation to estimate a life expectancy that is highly tailored to each person.

An individualized list of preventive care recommendations is created for a particular person by a separate recommendation algorithm (PSRS engine) based on age, gender, and personal preferences, utilizing set theory and USPSTF guidelines. This list of recommendations is then prioritized based on estimated impact on length of life. To predict the estimated impact of individual preventive interventions on life expectancy, a difference is calculated between the LE associated with the patient's current risk profile and the LE of a modified risk profile. For example, the HRA tool uses quintiles for the level of physical activity to predict mortality associated with various levels of physical activity. First, we select a physical activity level (e.g., the fourth quintile) that is considered desirable based on USPSTF guidelines (goal to be achieved). Then we compare the actual level of activity (e.g. first quintile or "sedentary") to the goal and adjust hazard (lambda) values accordingly in a consequent LE estimate to predict the life expectancy gained by achieving the goal. Repeating this procedure for

each recommendation results in a list of estimated impacts on life expectancy for each personalized intervention. Items are then ranked according to their efficacy (estimated effect size on length of life), but could also be ranked according to their cost, their acceptability, or their "effort effectiveness". In addition to LE estimates that are provided for clinicians, the HRA tool also delivers "patient-friendly" derivatives, including Real Age or Wellness Score [37] that are transformed from LE estimates. These parameters are represented both numerically and on a visual-analog scale (VAS) in the HRA report which is presented to the patient for discussion with his/her primary care clinician.

Validation of the Predictions of the HRA Tool

We ran three individual validation analyses on the output of the HRA tool, exploiting the advantages of particular clinical data sources to which we had access. In the first analysis, we selected a group of patients from our Oklahoma Longitudinal Assessment of Health Outcomes in Mature Adults (OKLAHOMA) Studies. This study followed 854 older adults between 2000 and 2010 in Oklahoma and included demographics, vital signs, laboratory measurements, disease information, and some psychosocial parameters on each patient. Patient profiles with the most comprehensive information (N=85) were entered into the HRA database. Life expectancy estimates were compared to observed mortality outcomes, anchoring each on the visit when the information entered into the HRA was elicited from the patient. The mean and standard error of the LE estimate were: 83.7 +/-0.59 years and the observed mean survival time was 83.9 +/- 0.61 years in the cohort (paired t-test, p value of 0.12), indicating that LE estimates were not significantly different from observed survival times. Similarly, when a correlation was calculated between [HRA LE estimate minus age at the time of the estimate] and [observed survival time minus age at the time of the estimate], the Pearson's correlation coefficient (r=0.91) suggested a high level of correlation between estimates and observations.

The OKLAHOMA Studies dataset followed individuals for a decade with reliable mortality outcomes, but it was not a rich source of clinical information, since only specific surveys responses were available as inputs for the HRA. Therefore, in a second validation exercise, we selected a small sample of our own patients at the University of Oklahoma HSC Department of Family Medicine (N=14) from several age groups, ethnicities, and both genders, who died in the past two years (maximum time-frame available in our electronic health record at that time), and conducted very thorough chart reviews to collect all available information pertaining to HRA risk factors. The mean and standard error of the LE estimate were: 73.5 +/-2.63 years and the observed mean survival time was 72.4 +/- 2.89 years, showing outcomes similar to the OKLAHOMA dataset, however the LE estimates followed observations more closely (the mean and standard error of difference between LE and survival time were 0.55 +/- 0.15 years, compared to the OKLAHOMA study: 0.92 +/-0.05) underscoring the importance of more detailed clinical information in the accuracy of LE predictions. The pilot study suggested that inclusion of behavioral and psychosocial determinants of health may have a strong impact on the accuracy of LE estimates. Medical records often lack sufficient detail on these clinical parameters and therefore make an HRA approach more desirable.

In a third validation exercise, we attempted to determine the discriminative performance of the HRA in relation to other existing prognostic tools, based on the method published recently by Siontis et al. [38] Using the OKLAHOMA Studies dataset, we estimated the area under the receiver operating characteristic curve (AUC-ROC) applying observed death within +/- 6 months of the HRA prediction as a differentiator between positive and negative outcomes. The AUC was 0.70, showing a reasonable ability to discriminate which was also comparable to a median AUC of 0.77 seen in a study of 118 existing tools for predicting mortality. [38]

Clinical Testing of the HRA Tool

We designed, implemented and pilot tested the novel, web-based HRA tool in four pair-matched intervention and control primary care practices (N=200). Outcomes were measured before and 12 months after the intervention using the HRA, patient surveys, and qualitative feedback. Intervention patients

received detailed feedback from the HRA and they were encouraged to discuss the HRA report at their next wellness visit in order to develop a personalized wellness plan.

Estimated life expectancy and its derivatives, including Real Age and Wellness Score were significantly impacted by the HRA implementation (P<0.001). The overall rate of 10 preventive maneuvers improved by 4.2% in the intervention group vs. control (P=0.001). The HRA improved the patient-centeredness of care, measured by the CAHPS PCC-10 survey (P=0.05). HRA use was strongly associated with better self-rated overall health (OR = 4.94; 95% CI, 3.85-6.36) and improved up-to-dateness for preventive services (OR = 1.22; 95% CI, 1.12-1.32). A generalized linear model suggested that increase in Wellness Score was associated with improvements in patient-centeredness of care, up-to-dateness for preventive services and being in the intervention group (all P<0.03). Patients were satisfied with their HRA-experience, found the HRA report relevant and motivating and thought that it increased their health awareness. Clinicians emphasized that the HRA tool helped them and their patients converge on high-impact, evidence-based preventive measures.

We concluded that despite study limitations, results suggest that a comprehensive, web-based, and goal-directed HRA tool can improve the receipt of preventive services, patient-centeredness of care, behavioral health outcomes, and various wellness indicators in primary care settings.

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