Annals of Internal Medicine | ORIGINAL RESEARCH

Personalized Estimates of Benefit From Preventive Care Guidelines

A Proof of Concept

Glen B. Taksler, PhD; Melanie Keshner, MSN, FNP; Angela Fagerlin, PhD; Negin Hajizadeh, MD, MPH; and R. Scott Braithwaite, MD, MSc

Background: The U.S. Preventive Services Task Force (USPSTF) makes recommendations for 60 distinct clinical services, but clinicians rarely have time to fully evaluate and implement the recommendations.

Objective: To complete a proof of concept for prioritization and personalization of USPSTF recommendations, using patient-specific clinical characteristics.

Design: Mathematical model.

Data Sources: USPSTF recommendations and supporting evidence and National Vital Statistics Reports.

Target Population: Nonpregnant adults.

Time Horizon: Lifetime.

Perspective: Individual.

Intervention: USPSTF grade A and B recommendations.

Outcome Measures: Personalized gain in life expectancy associated with each recommendation.

Results of Base-Case Analysis: Increases in life expectancy varied more than 100-fold across USPSTF recommendations, and the rank order of benefits varied considerably among patients. For an obese man aged 62 years who smoked and had hypercholesterolemia, hypertension, and a family history of colorectal cancer, the model's top 3 recommendations (from most to least gain in life expectancy) were tobacco cessation (adding 2.8 life-years), weight loss (adding 1.6 life-years), and blood pressure control (adding 0.8 life-year). Lower-ranked recommendations were a healthier diet, aspirin use, cholesterol reduction, colonoscopy, screening for abdominal aortic aneurysm, and HIV testing (each adding 0.1 to 0.3 life-years). For a person with the same characteristics plus uncontrolled type 2 diabetes mellitus, the model's top 3 recommendations were diabetes control, tobacco cessation, and weight loss (each adding 1.4 to 1.8 life-years).

Results of Sensitivity Analysis: Robust to variation of model inputs and satisfied face validity criteria.

Limitation: Expected adherence rates and quality of life were not considered.

Conclusion: Models of personalized preventive care may illustrate how magnitude and rank order of benefit associated with preventive guidelines vary across recommendations and patients. These predictions may help clinicians to prioritize USPSTF recommendations at the patient level.

Primary Funding Source: New York University School of Medicine.

Ann Intern Med. 2013;159:161-168. www.annals.org

For author affiliations, see end of text.

The U.S. Preventive Services Task Force (USPSTF) makes recommendations for 60 distinct clinical services (1). Yet, although receipt of preventive health care services has improved in the past decade, only approximately one half of recommended services are provided (1–3). Utilization remains alarmingly low for some services (for example, 48% of persons are not screened for colorectal cancer), and disparities in utilization may contribute to those in health outcomes (for example, 37% of black persons aged >65 years vs. 62% of white persons aged >65 years receive pneumococcal vaccinations) (4, 5).

An important reason why the U.S. health system does not implement prevention guidelines consistently may be insufficient personalization and prioritization at the point of care. The time available to fully evaluate and implement all relevant recommendations is widely considered inadequate (2–16) and would require more than 7 hours each day for a typical practice panel of 2500 patients (3), making prioritization essential. However, many studies suggest that clinicians do not know which USPSTF recommendations have the greatest benefit for each patient and therefore do not prioritize recommendations appropriately (17–20). A more systematic approach to prioritizing and personalizing guidelines may improve outcomes. Previous work suggests that increasing adherence to screening and treatment recommendations for hypertension, hyperlipidemia, aspirin chemoprophylaxis, and smoking cessation could each add 180 000 to 570 000 life-years to the U.S. population (21).

Moreover, optimal care may differ among patients. For example, a diabetic woman aged 80 years who is very frail may be more likely to be harmed than benefited by extremely tight blood sugar control, yet current decision supports may enforce rigid application of guidelines for this parameter (22, 23). Indeed, personalizing care is a main rationale for establishing patient-centered medical homes.

To facilitate personalized decision making at the point of care, we undertook a demonstration project to mathematically model an estimate of individualized magnitude of

See also:

Print

Editorial comment. 223
Summary for Patients. I-15

Web-Only

Supplements

Context

Professional organizations recommend so many screening and preventive services that clinicians cannot provide all of them to every patient.

Contribution

This work describes how to rank screening and preventive services according to increases in life expectancy and illustrates how the order changes with differences in demographic characteristics, medical conditions, and lifestyle choices.

Caution

These illustrations do not recognize differences in patient adherence to recommendations, differences in quality of life, and other important considerations.

Implication

It is possible for clinicians to incorporate patient-specific priorities for screening and preventive services into clinical care.

—The Editors

health benefit for each of the 25 USPSTF grade A and B guidelines applicable to nonpregnant adults (**Table**). Our model was intended as a proof-of-concept exercise rather than a finished product intended for widespread implementation.

METHODS

Model

We used a life-expectancy Markov model to prioritize preventive care services by examining each USPSTF recommendation in the context of a person's risk–benefit profile (**Figure 1**). First, we obtained the national average life expectancy for a patient's age, race, and sex (24). We then personalized estimates for life expectancy on the basis of the presence or absence of characteristics known to have a substantial effect on life expectancy that were influenced by USPSTF recommendations (tobacco use, alcohol use, body mass index, cardiovascular risk profile [hypertension, hypercholesterolemia, diabetes, and aspirin chemoprophylaxis], *BRCA1*/*BRCA2* status, osteoporosis, and depression). To do so, we adjusted mortality for a patient's individualized relative risk (RR). For example, 10-year all-cause mortality for women aged 50 years was 69 out of 1000 for current smokers and 37 out of 1000 for those who never smoked (25). Assuming a 20% prevalence of smoking (26), the current smokers had a 59% higher risk for death than the general population [all-cause mortality rate in current smokers ÷ all-cause mortality rate in the general population = 69 ÷ (20% × 69 + 80% × 37)], and the never smokers had a 15% lower risk for death than the general population [all-cause mortality rate in never smokers ÷ all-cause mortality rate in the general population = 37 ÷ (20% × 69 + 80% × 37)]. **Supplements 1** and **2** and **Table 1** of **Supplement 1** (available at www.annals.org) include a detailed description of methods, sources, and inputs.

Next, for each of the 25 USPSTF grade A and B recommendations on preventive care applicable to nonpregnant adults (**Table**), we simulated the change in personalized life expectancy after following each recommendation (that is, we followed a hypothetical cohort of persons "just like the patient" until death). At each age, the contribution to overall life expectancy was defined as the probability that a patient would survive to that age, multiplied by the expected benefit of preventive care, minus the expected risk. For example, the expected benefit from aspirin in women was the life expectancy associated with a 17% RR reduction in ischemic stroke (95% CI, 1% to 31%) (27). The expected risk was the life expectancy associated with a 10-year probability of gastrointestinal bleeding of 0.4% to 3.0%, depending on age, with an 80% survival rate (27, 28). When important clinical mediators were relevant (such as coronary heart disease for hyperlipidemia), we adjusted for the estimated probability of developing each mediator and associated survival rates (**Supplements 1** and **2** and **Table 1** of **Supplement 1**).

We then estimated how much longer a person would be expected to live after following each USPSTF recommendation (**Supplement 1**). Recommendations with a gain in life expectancy were considered advisable in our personalized setting.

Finally, we ranked USPSTF recommendations on the basis of the expected number of life-years gained to help identify the most important preventive care guidelines for each patient. Mindful of technology limitations in many health service settings, we implemented the model in Microsoft Excel 2007 (Microsoft, Redmond, Washington).

Inputs

Model inputs consisted of the 3 factors used to estimate baseline life expectancy—age, race, and sex—and additional patient-specific variables that modified the expected benefits and risks of each preventive care service (**Supplements 1** and **2** and **Table 1** of **Supplement 1**). Patient-specific variables and effect sizes were obtained from studies cited by USPSTF recommendations and comprised 9 categories: body mass index, vital signs, laboratories (lipid and sugar levels), medical history, lifestyle (tobacco use, alcohol use, and depression), current preventive care screenings, family history of disease, sexual practices, and reproductive history (for women only).

For example, 2 patient-specific variables were used to adjust for cervical cancer–specific mortality: reproductive history (parity of ≥5, age <18 years at first sexual intercourse, >5 sexual partners, or long-term oral contraceptive use) (RR, 2.5 times if ≥1 condition met) and smoking status (RR, 1.5 times for current smokers) (29, 30). Accordingly, the mortality benefit from cervical cancer

Table. **USPSTF Recommendations for Nonpregnant Adults***

Preventive Care Topic	USPSTF Recommendation	Grade	Date
AAA screening for men	One time, by ultrasonography, in men aged 65–75 y who have ever smoked	B	February 2005
Alcohol misuse counseling	Screening and behavioral counseling interventions	B	April 2004
Aspirin to prevent CVD			
Men	Men aged 45–79 y, when the potential benefit due to a reduction in MIs outweighs the potential harm due to an increase in gastrointestinal hemorrhage	A	March 2009
Women	Women aged 55–79 y, when the potential benefit of a reduction in ischemic strokes outweighs the potential harm of an increase in gastrointestinal hemorrhage	A	March 2009
Blood pressure screening in adults	Adults aged ≥18 y	A	December 2007
Counseling about BRCA screening	Referral of women whose family history is associated with an increased risk for deleterious mutations in *BRCA1/BRCA2* genes for genetic counseling and evaluation	B	September 2005
Breast cancer preventive medication	Discuss chemoprevention with women at high risk for breast cancer and low risk for adverse effects of chemoprevention	B	July 2002
Breast cancer screening	Biennial screening mammography for women aged 50–74 y	B	December 2009
Cervical cancer screening	Women aged 21–65 y with cytology every 3 y or, for women aged 30–65 y, screening with cytology plus HPV testing every 5 y	A	March 2012
Chlamydial infection screening for nonpregnant women	Sexually active, nonpregnant young women aged ≤24 y or older; nonpregnant women at increased risk	A	June 2007
Cholesterol abnormalities screening			
Men aged ≥35 y	Men aged ≥35 y	A	June 2008
Men aged <35 y	Men aged 20–35 y if at increased risk for CHD	B	June 2008
Women aged ≥45 y	Women aged ≥45 y if at increased risk for CHD	A	June 2008
Women aged <45 y	Women aged 20–45 y if at increased risk for CHD	B	June 2008
Colorectal cancer screening	Everyone aged 50–75 y, by FOBT, sigmoidoscopy, or colonoscopy	A	October 2008
Depression screening for adults	Screening when staff-assisted depression care supports are in place to ensure accurate diagnosis, effective treatment, and follow-up	B	December 2009
Diabetes screening	Screening for type 2 diabetes mellitus in asymptomatic adults with sustained blood pressure (treated or untreated) >135/80 mm Hg	B	June 2008
Gonorrhea screening for women	All sexually active women if at increased risk for infection	B	May 2005
Healthy diet counseling	Adults with hyperlipidemia and other known risk factors for CVD and diet-related chronic disease	B	January 2003
HIV screening	Everyone at increased risk for HIV infection	A	July 2005
Obesity screening and management for adults	Everyone and patients with a BMI ≥30 kg/m^2 should be provided with or referred to intensive, multicomponent behavioral interventions	B	June 2012
Osteoporosis screening for women	Women aged ≥65 y and younger women if at increased risk for osteoporotic fractures	B	January 2011
Counseling about sexually transmitted infections	High-intensity behavioral counseling for everyone at increased risk	B	October 2008
Tobacco use counseling and interventions	Ask all adults about tobacco use and provide tobacco cessation interventions for those who use tobacco products	A	April 2009
Syphilis screening	Everyone at increased risk for syphilis infection	A	July 2004

AAA = abdominal aortic aneurysm; BMI = body mass index; CHD = coronary heart disease; CVD = cardiovascular disease; FOBT = fecal occult blood test; HPV = human papillomavirus; MI = myocardial infarction; USPSTF = U.S. Preventive Services Task Force.
* Excludes folic acid supplementation because benefits accrue to an unborn child rather than the patient.

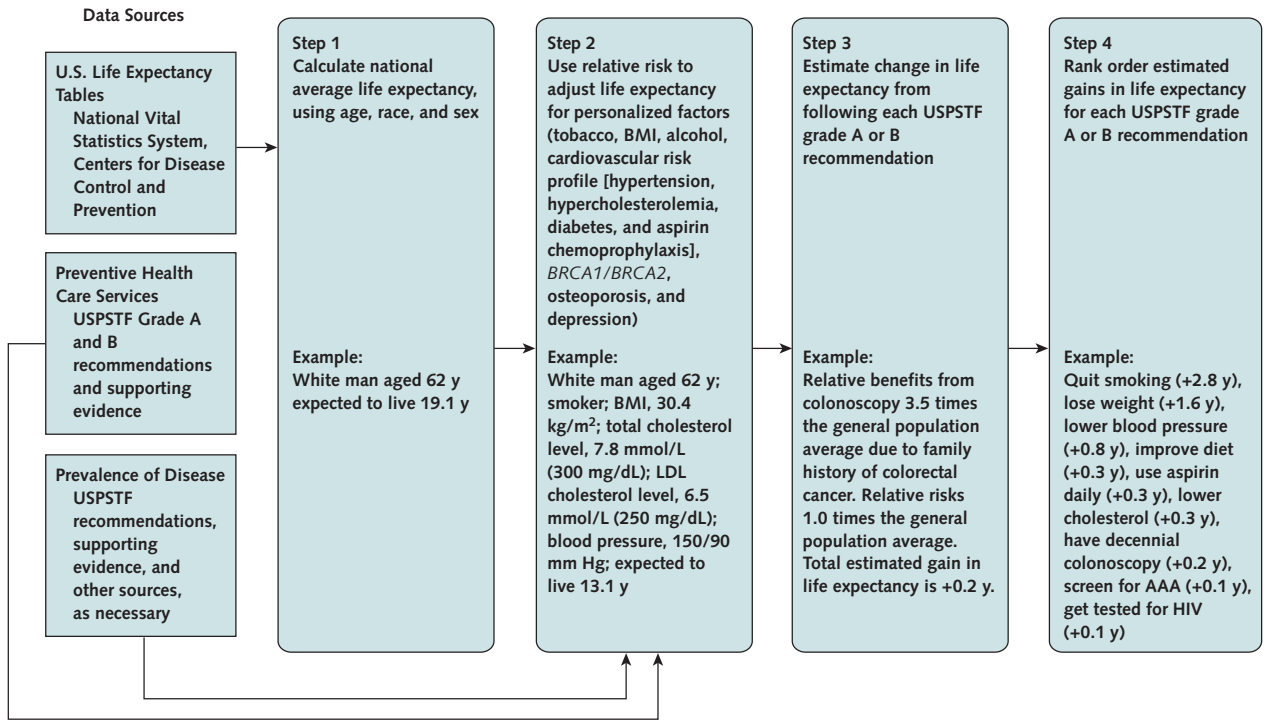
screening for a patient with both risk factors was 3.75 times (RR, 2.5 times × 1.5 times) the average mortality benefit for women of the same race and age. Fatal complications were also personalized; for example, patients receiving warfarin were estimated to have a 4.3-times higher risk for dying of colonoscopy (31). When there was no meaningful risk for fatal complications (for example, mammography), we considered other complications (such as anxiety) by assigning the lowest complication rate that calibrated the model to agree with the starting age for screening recommended by the USPSTF (**Supplement 1**).

Assumptions

To keep the model generalizable, scalable, and feasible in a patient setting, we made substantial simplifications. First, we assumed that age, race, and sex were sufficient to represent baseline (national average) life expectancy. Other factors, such as ethnicity, geography, and socioeconomic status, were not considered. Second, we assumed that personalized risks affected mortality at constant multiplicative rates (RRs). For example, a patient with hypercholesterolemia had 1.44 times the RR for abdominal aortic aneurysm (32), regardless of other risk factors. When estimates were available from existing literature, we allowed RRs to vary across age, race, and sex groups.

Third, the baseline benefits of preventive care were assumed to depend on 3 variables: the RR reduction from a preventive care service, the proportion of the population adhering to that service, and the delay for benefits to occur. For example, colonoscopy was associated with a reduction in RR in colorectal cancer–specific mortality of 70%,

Figure 1. **Personalized preventive care model.**



A 4-step process was used to create a personalized model of preventive health care recommendations. Detailed methods are available in **Supplement 1** (available at www.annals.org). AAA = abdominal aortic aneurysm; BMI = body mass index; LDL = low-density lipoprotein; USPSTF = U.S. Preventive Services Task Force.

but only 40% of the recommended population obtained screening (22, 23). If the entire recommended population was screened, then the national rate of colorectal cancer–specific mortality would be expected to decrease by 58% (1 − [RR with 100% adherence] ÷ [RR with 40% adherence] = 1 − [1 − 70% RR reduction] ÷ [40% adherence × {1 − 70% RR reduction} + 60% adherence × 100% RR]). Therefore, the average person having colonoscopy for the first time would benefit from a 58% risk reduction versus national mortality data. However, studies suggested a delay of 5 years to realize this risk reduction (22, 23). Delays were incorporated only when studies cited by the USPSTF had indicated a substantial period for benefits to accrue and were personalized when possible (**Supplements 1** and **2** and **Table 1** of **Supplement 1**).

Fourth, we did not discount time when estimating benefits, so patients were assumed to value immediate and future benefits equally. This assumption was used because the added complexity of attempting to identify personalized discount rates may have made the project infeasible.

Fifth, sexually transmitted diseases other than HIV rarely resulted in death (33) and therefore were not likely to be associated with meaningful changes in life expectancy. If screening was recommended, the smallest reported increment in life expectancy (0.1 life-year) was assigned.

Sixth, once screening or treatment was initiated, persons were assumed to continue at a personalized frequency until the model recommended stopping; for example, decennial colonoscopy until age 75 years (**Supplement 1**).

Finally, we assumed that the expected benefits of screening started to exceed the expected risk for fatal complications (or equivalent harms) at the age when initiation was first recommended. For age-specific USPSTF recommendations (such as recommending screening at age ≥50 years) that involved no direct risk for death, we imputed rates of serious complications on the basis of the age initiation threshold for USPSTF guidelines (34).

Scenarios

We considered 2 hypothetical patients, each with several chronic conditions and health risks. "Adam" was a white man aged 62 years who was obese (body mass index, 30.4 kg/m^2); smoked; and had hypercholesterolemia (total cholesterol level, 7.8 mmol/L [300 mg/dL]; low-density lipoprotein cholesterol level, 6.5 mmol/L [250 mg/dL]), hypertension (blood pressure, 150/90 mm Hg), and a family history of colorectal cancer (≥2 family members). "Bill" had the same characteristics plus uncontrolled type 2 diabetes mellitus (hemoglobin A_{1c} level, 9%). Whereas the USPSTF often stratifies recommendations by sex (**Table**),

we decided that both patients should be men to emphasize comorbidity-based differences. We chose age 62 years as the midpoint for aspirin chemoprophylaxis (selected men aged 45 to 79 years) and colorectal cancer screening (ages 50 to 75 years) as recommended by the USPSTF (**Table**).

Physicians may believe that tobacco cessation would be the most important priority in Adam but question whether diabetes control or tobacco cessation was more important in Bill. In both patients, physicians may question the relative priority of weight loss versus hypertension control. We analyzed model recommendations for these 2 patients to illustrate the model's capabilities and limitations.

Sensitivity Analysis

For each preventive care condition, we conducted a 1-way sensitivity analysis to assess the effect of varying input assumptions (such as race and sex) across plausible ranges. When available, plausible ranges were based on 95% CIs from studies referenced in USPSTF recommendations.

Face Validity

For each USPSTF guideline that considered age, we partitioned the simulated population into 4 subgroups on the basis of the presence or absence of relevant clinical characteristics (high vs. average benefit rates and high vs. average complication rates). For example, for colonoscopy, patients with HIV had high benefit rates because HIV increased the risk for colorectal cancer. Patients who received warfarin had high complication rates because warfarin increased the risk for bleeding-related complications from colonoscopy. The model was considered valid if it met 3 prespecified criteria for face validity: Preventive care was recommended at an earlier starting age for the group with high benefit and average complication rates, relative to all other groups; preventive care was recommended at a later starting age for groups with the same benefit rates but higher complication rates; and initiation of preventive care began within 5 years of the starting age recommended by the USPSTF in the group with average benefit and complication rates. For USPSTF guidelines that did not consider age, we compared initial age of recommendation predicted by the model with the implicit age at initiation ($\leq$18 years).

This study did not meet the criteria for human subjects review at the Institutional Review Board of New York University School of Medicine.

Role of the Funding Source

This study was funded by New York University School of Medicine. The funding source had no role in the design, conduct, and analysis of this study or in the decision to submit the manuscript for publication.

RESULTS

Calculation of Life Expectancy, Adjusted for Age, Race, Sex, and Risk Factors

Adam's life expectancy is 13.1 years (**Figure 2**, *A*), meaning that he has the life expectancy of an average white man aged 71 years. Bill's life expectancy is only 9.6 years, meaning that he has the life expectancy of an average white man aged 77 years.

Personalized Rank Order of Preventive Care Recommendations

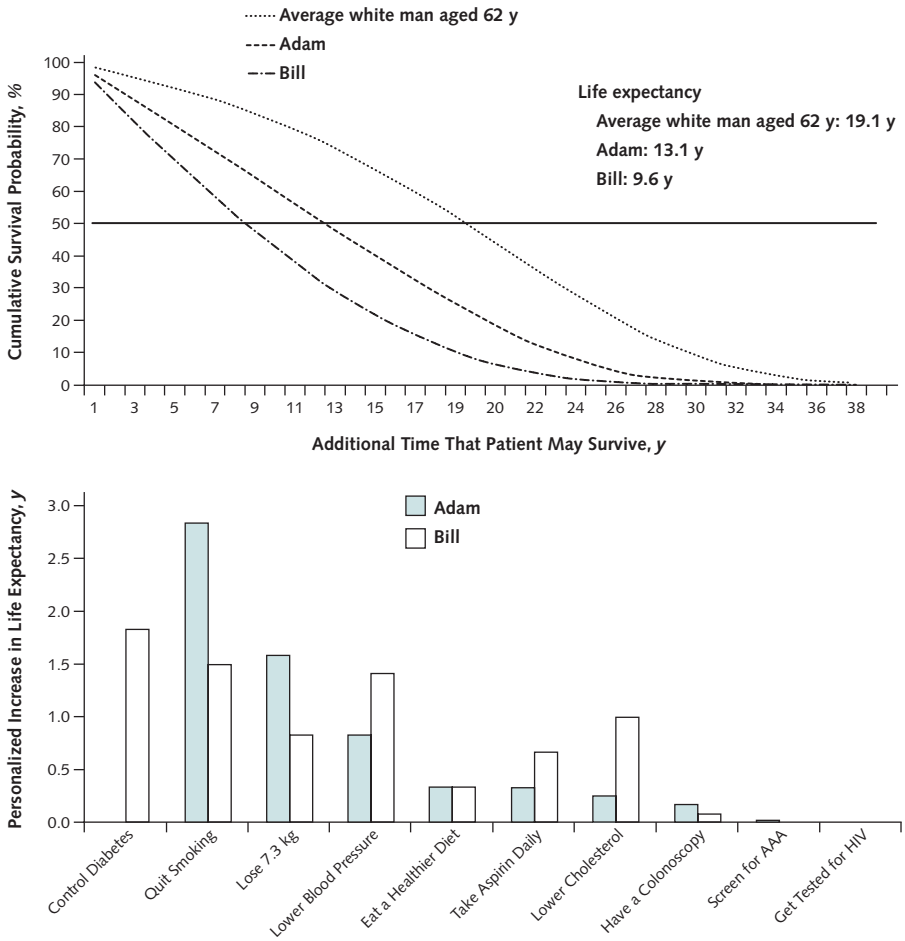
To improve Adam's life expectancy, the model's rank order of recommendations is to quit smoking (2.8 life-years gained); lose 7.3 kg or more (1.6 life-years gained); reduce blood pressure to 120/80 mm Hg (0.8 life-year gained); eat a healthier diet, such as eating more fruits and vegetables (0.3 life-year gained); use aspirin daily (0.3 life-year gained); lower the total cholesterol level to 5.2 mmol/L or less ($\leq$199 mg/dL) and low-density lipoprotein cholesterol level to 2.6 mmol/L or less ($\leq$100 mg/dL) (0.3 life-year gained); have decennial screening colonoscopy (0.2 life-year gained); have ultrasonography to screen for abdominal aortic aneurysm (0.1 life-year gained); and get tested for HIV (0.1 life-year gained) (**Figure 2**, *B*). Therefore, quitting smoking would confer a gain of 0.8 more life-year than lowering blood pressure and 2.0 more life-years than losing weight, suggesting a clear rank order of the model's top 3 recommendations.

To improve Bill's life expectancy, the model's top recommendation is to control diabetes (to hemoglobin A_{1c} level $\leq$7%; 1.8 life-years gained) (**Figure 2**, *B*), followed by quitting smoking (1.5 life-years gained) and lowering blood pressure (1.4 life-years gained). The benefit from tobacco cessation would be approximately one half that of Adam's (1.5 vs. 2.8 life-years gained) because of lower life expectancy in a patient with uncontrolled diabetes (**Figure 2**, *B*). Bill's rank order is less clear because the gain from each of the top 3 recommendations is similar (1.4 to 1.8 life-years gained).

Sensitivity Analysis

If Bill were black instead of white, tobacco cessation would become more important than diabetes control, with an associated gain in life expectancy as a black man of 1.8 years for tobacco cessation versus 1.6 years for diabetes control; as a white man, the numbers would be 1.5 years versus 1.8 years, respectively. This change would occur because the benefits of diabetes control are concentrated at later ages (for example, the risk for coronary heart disease increases 2.0 to 2.1 times for each race over 10 years), but black persons are less likely to survive to those ages (34.0% probability of Bill surviving 10 years if he were black vs. 40.8% if he were white). Therefore, if Bill were black, he would probably realize less benefit from diabetes control, and the rank order of the top 2 recommendations would reverse.

Figure 2. **Rank order of personalized preventive care recommendations.**



This figure shows personalized life expectancy for 2 hypothetical patients, plus an estimate of how much longer each patient may expect to live by following various preventive care recommendations. Estimates are shown for adherence to each individual recommendation; adherence to several recommendations may change life expectancy by less than the sum of individual recommendations. AAA = abdominal aortic aneurysm.

For a woman with Bill's characteristics (white or black), diabetes control would decrease in rank from first to fourth because of a lower risk for coronary heart disease in women that is not offset by a higher risk for stroke, with tobacco cessation, blood pressure control, and weight loss ranking first to third, respectively. The differences would be clinically meaningful, conferring approximately 0.8 life-year more for tobacco cessation than diabetes control. Preventive health care recommendations specific to women would rank low for gains in life expectancy, with mammography, osteoporosis testing, and Papanicolaou smear each conferring a gain of less than 0.1 life-year.

Sensitivity analyses were robust to variation of other model inputs (**Supplements 3** and **4** and **Supplement Figures 1** to **17**, available at www.annals.org).

General Observations

Across various hypothetical patients, tobacco cessation, diabetes control, weight loss, and blood pressure reduction were consistently among the highest-ranked guidelines. Screenings for abdominal aortic aneurysm, colorectal cancer, and breast cancer (in women with unknown *BRCA1/BRCA2* status) typically ranked lower.

Face Validity

The model satisfied face validity criteria across USPSTF recommendations (**Supplement 2** and **Tables 2** to **6** of **Supplement 2**; **Supplement 3**; and **Supplement 4** and **Supplement Figures 18** to **20**).

DISCUSSION

Previous work suggests that clinicians may find it difficult to personalize and prioritize preventive care guidelines (17–20) and that doing so effectively is time-consuming (3). For many, personalized medicine connotes efforts to assess a person's disease risk on the basis of genetics, such as the Human Genome Project (35) and the

role of *BRCA1*/*BRCA2* mutations in breast cancer (36). However, we construe personalized medicine far more broadly, as efforts to refine health care guidelines to meet the risk–benefit profile of a patient, considering genetics, personal and family history of disease, lifestyle, personal goals, and other defining characteristics. We were not the first investigators to attempt to personalize recommendations by mathematically modeling a broad range of diseases and risk factors. Notably, the Archimedes quantitative model personalizes risk for select conditions (especially diabetes, obesity, and cardiovascular disease) on the basis of in-depth representation of underlying biological mechanisms (37). We sought a more basic model that combined all major preventive care recommendations into a single, holistic proof-of-concept model.

In general, both our model and a recent *Lancet* Global Burden of Disease series consistently rank tobacco cessation, diabetes control, weight loss, and hypertension control as high priorities (38). Previous work has also emphasized services to prevent cardiovascular-associated disease (21). However, we shifted the focus from population burden of preventable morbidity and mortality to individual priorities. In our hypothetical scenarios, the distinct risk profiles of Adam and Bill (from both each other and the average white man aged 62 years) translated into distinct rank order and magnitude of benefit from preventive care guidelines. Although a busy clinician may find it difficult to personalize USPSTF preventive care recommendations, a mathematical model may offer insights that are sufficiently simple and actionable to incorporate into clinical workflow. Patients may find it difficult to understand risk metrics (39), so communication of personalized preventive care recommendations requires careful attention. However, the rank order of benefit may be communicated and used for clinical decision making even if life expectancy is not completely understood by patients. For example, Adam may be told that the most important thing he could do to improve his health is to quit smoking, followed by losing weight and lowering his blood pressure (**Figure 2**, *B*).

In an ongoing pilot study, we are incorporating this decision support into a busy primary care clinic (**Supplement 5**, available at www.annals.org). Electronic health records help to preidentify patients with the largest potential benefits in life expectancy if personalized recommendations were followed. A nurse practitioner then discusses these personalized recommendations with patients, pursuing a shared decision about goals a patient would like to achieve. A health coach then discusses practical ways to achieve them.

To improve clinical relevance, future versions of our framework must address several limitations. First, patient-level adherence rates should be incorporated into the decision support. For example, if a person has a 50% probability of adhering to hypertension medication (40) but only a 25% probability of successfully completing a tobacco cessation program (41), then the relative importance of tobacco cessation should decline by one half. Second, to improve patient-centeredness, metrics other than life expectancy (such as quality of life and patient preferences) should be included. Third, to the degree that racial differences in life expectancy are mediated through socioeconomic status, such variables as income and education should be incorporated into our framework. For example, it is currently possible that the life expectancy of a highly educated black person may be better represented by white race, where persons have higher average socioeconomic status. Similarly, explicit modeling of other risk factors (such as specific treatments) could improve accuracy. Fourth, an ideal model should consider interaction among recommendations. For example, we estimated the effects of weight loss at a patient's current blood pressure but not how much blood pressure may decrease because of weight loss. Fifth, the model would benefit from CIs surrounding several sources of data. Finally, baseline life expectancy should consider dominant comorbid conditions that substantially affect mortality risk, such as previous diagnosis of cancer.

Models of personalized preventive care may help clinicians prioritize USPSTF recommendations at the patient level. Future work may help to determine whether model-based personalization is feasible at the point of care and is associated with improved health outcomes.

From New York University School of Medicine, New York, New York, and University of Michigan, Ann Arbor, Ann Arbor, Michigan.

Grant Support: By seed funds from New York University School of Medicine.

Potential Conflicts of Interest: Disclosures can be viewed at www.acponline.org/authors/icmje/ConflictOfInterestForms.do?msNum=M12-2938.

Reproducible Research Statement: *Study protocol:* Available in **Supplement 1** (available at www.annals.org). *Statistical code:* Template available from Dr. Taksler (e-mail, glentaksler@gmail.com). Nonacademic researchers may be required to sign a written use agreement. *Data set:* Not available.

Requests for Single Reprints: Glen B. Taksler, PhD, Departments of Population Health and Medicine, New York University School of Medicine, 550 First Avenue, Translational Research Building, 6th Floor, New York, NY 10016; e-mail, glentaksler@gmail.com.

Current author addresses and author contributions are available at www.annals.org.

References

1. **U.S. Preventive Services Task Force.** USPSTF A–Z Topic Guide. Accessed at www.uspreventiveservicestaskforce.org/uspstopics.htm on 6 June 2013.
2. **Tai-Seale M, McGuire TG, Zhang W.** Time allocation in primary care office visits. Health Serv Res. 2007;42:71-94. [PMID: 17850524]
3. **Yarnall KS, Pollak KI, Østbye T, Krause KM, Michener JL.** Primary care: is there enough time for prevention? Am J Public Health. 2003;93:635-41. [PMID: 12660210]

4. **Maciosek MV, Coffield AB, Edwards NM, Flottemesch TJ, Goodman MJ, Solberg LI.** Priorities among effective clinical preventive services: results of a systematic review and analysis. Am J Prev Med. 2006;31:52-61. [PMID: 16777543]
5. **Partnership for Prevention.** Preventive Care: A National Profile on Use, Disparities, and Health Benefits. 2007;1-43. Accessed at www.prevent.org/data/files/initiatives/ncpppreventivecarereport.pdf on 6 June 2013.
6. **Østbye T, Yarnall KS, Krause KM, Pollak KI, Gradison M, Michener JL.** Is there time for management of patients with chronic diseases in primary care? Ann Fam Med. 2005;3:209-14. [PMID: 15928223]
7. **Fiscella K, Epstein RM.** So much to do, so little time: care for the socially disadvantaged and the 15-minute visit. Arch Intern Med. 2008;168:1843-52. [PMID: 18809810]
8. **Flocke SA, Frank SH, Wenger DA.** Addressing multiple problems in the family practice office visit. J Fam Pract. 2001;50:211-6. [PMID: 11252208]
9. **Pimlott N.** Preventive care: so many recommendations, so little time. CMAJ. 2005;173:1345-6. [PMID: 16301703]
10. **Tarn DM, Paterniti DA, Kravitz RL, Heritage J, Liu H, Kim S, et al.** How much time does it take to prescribe a new medication? Patient Educ Couns. 2008;72:311-9. [PMID: 18406562]
11. **Burdi MD, Baker LC.** Physicians' perceptions of autonomy and satisfaction in California. Health Aff (Millwood). 1999;18:134-45. [PMID: 10425851]
12. **Hadley J, Mitchell JM, Sulmasy DP, Bloche MG.** Perceived financial incentives, HMO market penetration, and physicians' practice styles and satisfaction. Health Serv Res. 1999;34:307-21. [PMID: 10199677]
13. **Nutting PA, Rost K, Smith J, Werner JJ, Elliot C.** Competing demands from physical problems: effect on initiating and completing depression care over 6 months. Arch Fam Med. 2000;9:1059-64. [PMID: 11115208]
14. **Linzer M, Konrad TR, Douglas J, McMurray JE, Pathman DE, Williams ES, et al.** Managed care, time pressure, and physician job satisfaction: results from the physician worklife study. J Gen Intern Med. 2000;15:441-50. [PMID: 10940129]
15. **Mechanic D.** Physician discontent: challenges and opportunities. JAMA. 2003;290:941-6. [PMID: 12928472]
16. **Nutting PA, Baier M, Werner JJ, Cutter G, Conry C, Stewart L.** Competing demands in the office visit: what influences mammography recommendations? J Am Board Fam Pract. 2001;14:352-61. [PMID: 11572540]
17. **Piette JD, Kerr EA.** The impact of comorbid chronic conditions on diabetes care. Diabetes Care. 2006;29:725-31. [PMID: 16505540]
18. **O'Connor PJ.** Setting evidence-based priorities for diabetes care improvement [Editorial]. Int J Qual Health Care. 2003;15:283-5. [PMID: 12930043]
19. **Braithwaite RS, Concato J, Chang CC, Roberts MS, Justice AC.** A framework for tailoring clinical guidelines to comorbidity at the point of care. Arch Intern Med. 2007;167:2361-5. [PMID: 18039996]
20. **Walter LC, Bertenthal D, Lindquist K, Konety BR.** PSA screening among elderly men with limited life expectancies. JAMA. 2006;296:2336-42. [PMID: 17105796]
21. **Farley TA, Dalal MA, Mostashari F, Frieden TR.** Deaths preventable in the U.S. by improvements in use of clinical preventive services. Am J Prev Med. 2010;38:600-9. [PMID: 20494236]
22. **Braithwaite RS, Fiellin D, Justice AC.** The payoff time: a flexible framework to help clinicians decide when patients with comorbid disease are not likely to benefit from practice guidelines. Med Care. 2009;47:610-7. [PMID: 19433991]
23. **Braithwaite RS.** Can life expectancy and QALYs be improved by a framework for deciding whether to apply clinical guidelines to patients with severe comorbid disease? Med Decis Making. 2011;31:582-95. [PMID: 21310855]
24. **Arias E, Rostron BL, Tejada-Vera B.** United States life tables, 2005. Natl Vital Stat Rep. 2010;58:1-132. [PMID: 20578408]
25. **Woloshin S, Schwartz LM, Welch HG.** The risk of death by age, sex, and smoking status in the United States: putting health risks in context. J Natl Cancer Inst. 2008;100:845-53. [PMID: 18544745]
26. **Centers for Disease Control and Prevention (CDC).** Current cigarette smoking prevalence among working adults—United States, 2004-2010. MMWR Morb Mortal Wkly Rep. 2011;60:1305-9. [PMID: 21956406]
27. **U.S. Preventive Services Task Force.** Aspirin for the prevention of cardiovascular disease: U.S. Preventive Services Task Force recommendation statement. Ann Intern Med. 2009;150:396-404. [PMID: 19293072]
28. **Straube S, Tramèr MR, Moore RA, Derry S, McQuay HJ.** Mortality with upper gastrointestinal bleeding and perforation: effects of time and NSAID use. BMC Gastroenterol. 2009;9:41. [PMID: 19500343]
29. **Vesco KK, Whitlock EP, Eder M, Lin J, Burda BU, Senger CA, et al.** Screening for Cervical Cancer: A Systematic Evidence Review for the U.S. Preventive Services Task Force. Evidence Synthesis No. 86. AHRQ Publication no. 11-05156-EF-1. Rockville, MD: Agency for Healthcare Research and Quality; 2011.
30. **Berrington de González A, Green J; International Collaboration of Epidemiological Studies of Cervical Cancer.** Comparison of risk factors for invasive squamous cell carcinoma and adenocarcinoma of the cervix: collaborative reanalysis of individual data on 8,097 women with squamous cell carcinoma and 1,374 women with adenocarcinoma from 12 epidemiological studies. Int J Cancer. 2007;120:885-91. [PMID: 17131323]
31. **Weinberg DS.** In the Clinic. Colorectal cancer screening. Ann Intern Med. 2008;148:ITC2-1-ITC2-16. [PMID: 18252680]
32. **Fleming C, Whitlock E, Beil T, Lederle F.** Primary Care Screening for Abdominal Aortic Aneurysm. Evidence Syntheses no. 35. Rockville, MD: Agency for Healthcare Research and Quality; 2005.
33. **Centers for Disease Control and Prevention, National Center for Health Statistics.** CDC WONDER. About Underlying Cause of Death, 1999–2010. Accessed at http://wonder.cdc.gov/ucd-icd10.html on 27 August 2012.
34. **Nattinger AB.** In the clinic. Breast cancer screening and prevention. Ann Intern Med. 2010;152:ITC4-1. [PMID: 20368645]
35. Human Genome Project Information. U.S. Department of Energy Office of Science, Office of Biological and Environmental Research, Human Genome Program. Accessed at www.ornl.gov/sci/techresources/Human_Genome/home.shtml on 14 March 2013.
36. **Nelson HD, Huffman LH, Fu R, Harris EL; U.S. Preventive Services Task Force.** Genetic risk assessment and BRCA mutation testing for breast and ovarian cancer susceptibility: systematic evidence review for the U.S. Preventive Services Task Force. Ann Intern Med. 2005;143:362-79. [PMID: 16144895]
37. **Eddy D.** Bringing health economic modeling to the 21st century. Value Health. 2006;9:168-78. [PMID: 16689710]
38. **Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al.** A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380:2224-60. [PMID: 23245609]
39. **Harle CA, Downs JS, Padman R.** Effectiveness of personalized and interactive health risk calculators: a randomized trial. Med Decis Making. 2012;32:594-605. [PMID: 22247421]
40. **Feldman R, Bacher M, Campbell N, Drover A, Chockalingam A.** Adherence to pharmacologic management of hypertension. Can J Public Health. 1998;89:I16-8. [PMID: 9813921]
41. **Fiore MC, Novotny TE, Pierce JP, Giovino GA, Hatziandreu EJ, Newcomb PA, et al.** Methods used to quit smoking in the United States. Do cessation programs help? JAMA. 1990;263:2760-5. [PMID: 2271019]

Current Author Addresses: Drs. Taksler, Hajizadeh, and Braithwaite and Ms. Keshner: Departments of Population Health and Medicine, New York University School of Medicine, 550 First Avenue, Translational Research Building, 6th Floor, New York, NY 10016.
Dr. Fagerlin: Division of General Internal Medicine, University of Michigan, 2800 Plymouth Road, Building 16, Room 421W, Ann Arbor, MI 48109.

Author Contributions: Conception and design: G.B. Taksler, M. Keshner, N. Hajizadeh, R.S. Braithwaite.
Analysis and interpretation of the data: G.B. Taksler, M. Keshner, N. Hajizadeh, R.S. Braithwaite.
Drafting of the article: G.B. Taksler, N. Hajizadeh, R.S. Braithwaite.
Critical revision of the article for important intellectual content: G.B. Taksler, A. Fagerlin, R.S. Braithwaite.
Final approval of the article: G.B. Taksler, M. Keshner, A. Fagerlin, R.S. Braithwaite.
Provision of study materials or patients: M. Keshner.
Statistical expertise: G.B. Taksler.
Administrative, technical, or logistic support: G.B. Taksler.
Collection and assembly of data: G.B. Taksler, M. Keshner.