

## The Role of Resource Allocation Models in Selecting Clinical Preventive Services

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### **Abstract**

**Objective:** To demonstrate the potential value and current limitations of using resource allocation models for selecting health services.

**Design:** To identify the most efficient mix of preventive services that could be offered by a managed care organization (MCO) for a fixed budget, an optimization model (greatest number of life years saved) and a cost-effectiveness model (rank order of most to least cost effective) were developed. Because of the lack of cost-effectiveness analyses that met the study criteria, only 9 preventive services were selected to demonstrate each model.

**Patients and Methods:** The 2 models were applied to a hypothetical managed care population of 100,000 enrollees with age, sex, and risk distribution similar to that of the US population. Data for the input variables were obtained from cost-effectiveness studies of 9 preventive services. Model variables included the target population, percent of enrollees who received the preventive service, the cost of the preventive service, life years saved, and cost-effectiveness ratios.

**Results:** The models demonstrated that efficient allocation of finite resources can be achieved. When budgets are limited, different premises between the

2 models may yield different health consequences. However, as the budgets were increased, results from the 2 models were more closely aligned.

**Conclusions:** Resource allocation models have the potential for assisting MCOs in selecting a set of preventive services that will maximize population health. Before this potential can be fully realized, additional methodological development and cost-effectiveness studies are needed. The use of resource allocation should be examined for selecting all healthcare services.

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One goal of health policy should be to develop a healthcare system within each community that optimally uses the available resources to improve the health of the population. In a perfectly functioning market, this would occur by market forces. Consumers would have information about the quality and price of each product and would buy the health-maximizing quantities of each product, thus rendering resource allocation unnecessary. However, in most instances, the healthcare market is imperfect,<sup>1</sup> in part because consumers do not have sufficient information about the quality or price of services. Furthermore, transactions for health services do not involve only the consumer and the provider; decisions about which services will be covered in a health plan are generally made by the purchaser (eg, employers or the government) in consultation with the health plan.

How to spend limited resources more efficiently among competing services is generally becoming an inevitable and practical problem for purchasers, managed care organizations (MCOs), and state and

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local health departments. As decision makers, they must make tradeoffs to allocate their finite resources on one basis or another. Furthermore, they must make selections that maximize the health of the populations they serve. This outcomes-oriented approach is part of a general trend toward what has been referred to as purchasing population health.<sup>2</sup> Thus, market failure in the healthcare system, the demand for improvements in population health, and finite resources for competing intervention services have created a theoretical justification for a rational model to assist in decision-making. Resource allocation is such a model.

The general approach for resource allocation is to use optimization models to identify the optimal mix of competing services. These models translate a real-world problem into a set of mathematical equations, maximizing or minimizing an objective function subject to certain constraints. Such models use mathematical procedures to find an optimal solution for allocating finite resources. For many years, optimization models have been used successfully for resource allocation in such fields as agriculture, business, environmental protection, and community development (eg, production mix decisions, capital investment decisions, and extraction decisions for natural resources). However, only limited attempts have been made to apply such tools to the health sector. Although there is some work on optimization techniques, it either focuses on mathematical programming frameworks,<sup>3</sup> or applies such techniques to a hypothetical population with characteristics very different from the US population.<sup>4</sup> To date, little research has been conducted on applying such techniques to US health sector decisions. In the healthcare field, most published economic evaluation studies are cost-effectiveness analyses of preventive, diagnostic, and therapeutic interventions, which can be used to assess the efficiency of alternative options. However, cost-effectiveness analysis does not consider the impact of fixed budgets when decision makers must allocate their finite resources to a mix of health services. Another approach to rationally allocate resources and inform decision making needs to be developed. Such an approach would incorporate information from cost-effectiveness analyses, budget constraints, and population health characteristics into an optimal resource allocation model to achieve the greatest improvement in a population's health status per dollar invested for a fixed budget.

Such models would be useful in the healthcare decision process in many settings. For example, the

Health Care Financing Administration could use resource allocation in the selection of new services, particularly preventive services, covered by Medicare. Similarly, resource allocation models would assist states in determining the health services provided by Medicaid. Employers could use these types of models to determine what health services should be covered, and under what conditions, in the health plans they offer. Even consumer groups can use such models to assess the efficiency of health plans and healthcare offered to their constituents. This study examines the use of 2 resource allocation models to select the package of preventive services offered by an MCO.

The first step in selecting an efficient set of health services is to identify the safe and effective options. Guidelines for screening, diagnostic, and treatment practices are published by federal health agencies such as the Centers for Disease Control and Prevention and by the professional medical associations.

In 1996, the US Preventive Services Task Force (USPSTF) published the Guide to Clinical Preventive Services, which made recommendations for safe and effective clinical preventive services.<sup>5</sup> Based on the assessments of efficacy and effectiveness, the Guide offers recommendations for the prevention of approximately 80 conditions. The recommendations are graded on a 5-point scale (A-E), reflecting the strength of evidence in support of the clinical preventive service. An "A" rating means that there is good evidence to support the recommendation and a "B" rating means that there is fair evidence for such support. Evidence-based methodology was used to provide current and scientifically defensible information about the effectiveness of the recommended clinical preventive services. More than 60 clinical preventive services have been determined to be safe and effective; implementation of all of them may not be financially possible in all healthcare settings.

Translating these guidelines into practice requires a decision-making tool, using the Guide to determine (1) which services should be selected, (2) the target population for each service, and (3) when and how each service should be performed. Our goal was to develop such a tool. We began by selecting a set of potential preventive services that an MCO can provide to a hypothetical enrolled population. We developed 2 demonstration models with multiple components and fixed budgets to select a set of clinical preventive services the MCO should offer. Because of the limited cost-effectiveness data available, we did not attempt to recommend specific pre-

ventive services. The models are hypothetical and are for demonstration purposes only.

... METHODS ...

We developed 2 resource allocation models to identify the most efficient mix of preventive services that could be offered by an MCO. The first model (Model I) has an objective function that maximizes the health outcome—defined here as life years (LYs) saved—for a fixed annual budget for preventive services. The second model (Model II) ranks preventive services by their cost-effectiveness (CE) ratios and allocates the fixed preventive services budget in descending order of priority from the most cost effective to the least cost effective. The specifications for each model are presented in Table 1.

Cost effectiveness is determined not only by the effectiveness of the preventive service but by the tradeoffs between the cost of the service and future costs associated with the disease to be prevented. Model I accounts for only the cost and the effective-

ness of the preventive service; future disease costs are not included. Model II attempts to account for the benefits of averting future disease-related costs by ranking the CE ratios. The CE ratio includes information about both the net cost and the effectiveness of the preventive service. Net cost is defined as the costs of the preventive service plus the costs of any associated side effects plus costs induced by the preventive service (eg, if a coronary bypass operation delays a fatal heart attack by 5 years, the costs of an ongoing treatment during added years of life, such as lifelong antihypertensive therapy and its side effects, are always included) minus the costs saved by preventing the disease. Although not included in the models developed for this study, additional constraints, such as the mandatory inclusion of a preventive service (eg, neonatal screening for hemoglobinopathies) and other political and administrative constraints, can be added to either model (Table 1).

We used the optimization software *What's Best*<sup>6</sup> to run Model I. The package will achieve the highest outcome (number of LYs saved) for a fixed budget level. We used *Excel* to develop and implement

**Table 1.** Resource Allocation Models Used in Study

<p><b>Model I: Optimization model (allocation by maximizing outcome)</b></p> <p><b>Key equations:</b>                  Objective function: <math>\text{Max } \sum X_i * Y_i = X_1 * Y_1 + X_2 * Y_2 + X_3 * Y_3 + \dots + X_9 * Y_9</math>                  (<math>\sum X_i * Y_i</math>: maximum outcome achieved by the package)                  Budget constraint: <math>\sum X_i * C_i \leq B</math>                  Other constraints: <math>X_i = 1</math> (for mandatory prevention activity)                  (Constraints such as political and administrative constraints can be incorporated in this model after being identified)</p> <p><b>Key variables of the model:</b>  <i>i</i>: prevention activity  <i>B</i>: budget for a package of prevention activities  <i>Y<sub>i</sub></i>: outcome of prevention activity <i>i</i> given a hypothetical population  <i>C<sub>i</sub></i>: cost of prevention activity <i>i</i> (short-term cost)  <i>X<sub>i</sub></i>: a zero/one integer variable, where <math>X_i = 1</math> if the <i>i</i>th prevention is to be undertaken, and <math>X_i = 0</math> if not</p> <p>For the development of this model, we used optimization software <i>What's Best</i>.<sup>6</sup> The optimal package will achieve the highest outcome given a budget level.</p> <p><b>Model II: Cost-effectiveness model (allocation by the ranking of CE ratios)</b></p> <p><b>Key variable:</b>                  Cost-effectiveness ratio (CE ratio)                  CE ratio = net cost/outcome                  net cost = prevention costs + costs of side effects + costs induced by preventive services - medical costs averted</p> <p>The resources are allocated in the order of cost effectiveness, with the most cost-effective activity given the first priority, until the budget is exhausted. For this model, we used <i>Excel</i> for the calculations.</p>
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Model II. The program allocated the fixed budget to preventive services in order of cost effectiveness, with the most cost-effective activity given first priority, until the budget was exhausted. We applied the 2 models to a hypothetical MCO population of 100,000 patients.

### Preventive Services

We selected 9 preventive services to demonstrate each model (Table 2). Criteria for selecting these services included: (1) the clinical preventive service had received either an "A" or a "B" rating in the Guide; (2) the service was targeted at a disease for which preventing mortality was the primary outcome; and (3) published cost-effectiveness studies existed that addressed the recommended preventive

service in which LYs saved was the primary health outcome. These criteria limited the potential set of preventive services that could be included in the models. The first criterion limited the set to scientifically proven interventions. The second criterion was chosen in an attempt to select preventive services with comparable health outcomes. Ideally, we would have selected a health outcome that incorporated the effects of morbidity on quality of life. However, this would have reduced the number of prevention services below a reasonable number needed to test the 2 models. Finally, the available cost-effectiveness studies that could meet the first 2 selection criteria were limited. Interventions in many studies differ from the Guide recommendations. For example, in the case of cervical cancer

**Table 2.** Baseline Data Used in the Two Models

Clinical Preventive Service (CPS)	Target Population*	% of MCO Enrollees in Target Population <sup>†</sup>	% of MCO Enrollees in Target Population Who Receive the CPS	Cost of CPS Per Enrollee Receiving Service (\$)‡	Average Number of Life Years Saved <sup>§</sup>	Cost-effectiveness Ratio (Net Cost per Life Year Saved) (\$)
Cervical cancer screening	Women ages 15 to 74	12.43	90	23.40	0.027	22,104
Breast cancer screening	Women ages 50 to 69	9.06	70	95.00	0.040	46,987
Colorectal cancer screening	All persons ages 50 to 74	20.29	18	48.00	0.023	18,715
Tuberculin infection screening	High-risk persons	2.00	60	15.00	0.012	-473
Human immunodeficiency virus screening	All pregnant women	1.41	78	35.00	0.003	-3281
Counseling to prevent tobacco use	All persons who smoke	18.28	80	9.00	0.009	14,838
Influenza A immunization	All persons age 65 and older	12.50	61	7.30	0.077	2973
Hepatitis B screening	All pregnant women	1.41	85	36.00	0.002	65,049
Physical activity counseling	All persons physically inactive	42.40	80	7.30	0.104	2323

\* A hypothetical managed care organization (MCO) population was used in these models.

†Percent of MCO enrollees who should receive the recommended service in a 1-year period.

‡The cost for the recommended CPS is taken from the *1996 Physicians Fee and Coding Guide*.<sup>17</sup>

§Average number of life years per MCO enrollee who receives CPS

screening, the Guide recommends routine Papanicolaou (Pap) test screening every 3 years for all women who are or have been sexually active, but few studies examined this interval. Cost-effectiveness analyses usually assess individual preventive services, and outcomes are typically measured in natural units (eg, cases of cervical cancer prevented); studies that use LYs saved as an outcome measure are limited. Although the Panel on Cost Effectiveness in Health and Medicine recently recommended use of quality adjusted life years (QALYs) as the health outcome,<sup>7</sup> studies using QALYs are still scarce.

The 9 clinical preventive services that met the inclusion criteria are listed as specified by the USPSTF.<sup>5</sup>

- Screening for cervical cancer—Routine screening for cervical cancer with Pap testing is recommended for all women who are or have been sexually active and who have a cervix. Pap testing should begin at the onset of sexual activity and should be repeated every 3 years (pg. 104).
- Screening for breast cancer—Routine screening for breast cancer every 1 to 2 years, with mammography alone or mammography and annual clinical breast examination, is recommended for women aged 50 to 69 years (pg. 73).
- Screening for colorectal cancer—Screening for colorectal cancer is recommended for all persons aged 50 and older with annual fecal occult blood testing, sigmoidoscopy (periodicity unspecified), or both (pg. 89).
- Screening for tuberculin infection—Tuberculin skin testing is recommended for asymptomatic high-risk persons (pg. 277).
- Screening for human immunodeficiency virus (HIV)—Screening is recommended for all pregnant women at risk for HIV infection, including all women who live in states, counties, or cities with increased prevalence of HIV infection (pg. 303).
- Counseling to prevent tobacco use—Tobacco cessation counseling on a regular basis is recommended for all persons who use tobacco products (pg. 597).
- Adult immunizations including chemoprophylaxis against influenza A—Annual influenza vaccine is recommended for all persons aged 65 and over and persons in select high-risk groups (pg. 791).
- Screening for hepatitis B—Screening with hepatitis B surface antigen (HbsAg) to detect active (acute or chronic) hepatitis B virus (HBV) infection is recommended for all pregnant women at their first prenatal visit. The test may be repeated in the third trimester in women who are initially HbsAg negative and who are at increased risk of HBV infection during pregnancy (pg. 269).
- Counseling to promote physical activity—Counseling patients to incorporate regular physical activity into their daily routines is recommended to prevent coronary heart disease, hypertension, obesity, and diabetes (pg. 611).

### Variables

The models contain 5 variables specific to each clinical preventive service (CPS) (Table 2). Four of these variables are common to both models: the target population, the percentage of the MCO enrollees in the target population who should receive the CPS each year, the percentage of the MCO enrollees who actually receive the CPS; and the delivery cost. The average number of life years saved per enrollee who receives the CPS is used in the optimization model (Model I) and the cost-effectiveness ratio is used in the cost-effectiveness model (Model II).

*Target Population.* We used the target population specified in the Guide<sup>5</sup> with a few minor modifications. We arbitrarily selected an upper age limit of 74 years for cervical cancer screening and colorectal cancer screening because the USPSTF did not set an upper limit. We limited HIV and hepatitis B screening to pregnant women because of the availability of cost-effectiveness studies. We also limited physical activity counseling to physically inactive adults.

*Percent of Enrollees in the Target Population.* We assumed that the hypothetical MCO population we used for the 2 models was representative of the US population. We obtained the age and sex distribution from the 1990 US census. We used information from the cost-effectiveness studies for each CPS for the distribution of risk factors in the population, eg, the percentage of all persons who smoke, the percentage of women who are pregnant in a given year.<sup>8-16</sup> This provides the approximate scale for most individual managed care plans which, with the addition of Medicare and Medicaid populations, gradually care for a cross-section of the US population. For services not provided annually, we divided the percentage of enrollees in the target population by the periodicity of the CPS. For example, only 12.43% (one third of women ages 15 to 74 years of age) are screened for cervical cancer each year.

*Percent of MCO Enrollees in the Target Population That Receive the CPS.* For a variety of reasons, not all enrollees in the target population receive the recommended CPS. We used data from several sources to attempt to realistically model the percentage of the enrolled population who would receive the CPS if it were offered by the MCO. We used data from the Centers for Disease Control and Prevention's (CDC) 1995 Behavioral Risk Factor

Surveillance System to estimate the colorectal cancer screening rate and the system's 1996 data to estimate the rates of cervical and breast cancer screening and influenza A immunization. We used the authors' assumptions for the percentage of pregnant women who would accept HIV testing.<sup>8</sup> Because of lack of data we used expert opinion to estimate the number of pregnant women who would accept hepatitis B testing. For the 2 counseling services, exercise and smoking cessation, this variable is the estimate of the percentage of MCO enrollees in the target population who accept the counseling, not the percentage who follow the advice given to stop smoking or to engage in regular exercise. The estimates for percentage of enrollees who accept the 2 counseling services are based on expert opinion.

*Cost per MCO Enrollee Receiving the CPS.* We used the lower end of the fee range recommended in the HealthCare Consultants of America, Inc 1996 *Physicians Fee and Coding Guide*<sup>17</sup> for the annual cost of the preventive service. Only the costs of the procedures specified in the recommendation are included in the annual cost. For example, only the costs of a mammogram and a clinical breast examination are included for breast cancer screening. Costs of biopsies and further follow-up procedures are not included. For the 2 counseling services, we assigned 10% of a routine physician visit to the service and prorated the cost accordingly.

*Average Number of LYs Saved per MCO Enrollee Receiving the CPS.* The LYs saved were obtained from published cost-effectiveness studies.<sup>8-16</sup> The studies use different assumptions, methodologies, and primary data sources. We adjusted key variables to a standard format. We converted health outcomes reported in natural units to LYs saved. We used standard life expectancy tables<sup>18</sup> to convert deaths prevented into LYs saved.

*Cost-Effectiveness Ratio.* The CE ratio is defined as the net cost of the CPS (cost of CPS minus medical costs prevented) divided by the LYs saved by the service. The cost effectiveness of the CPS is compared with no CPS. The CE ratios were obtained from cost-effectiveness studies.<sup>8-16</sup> After recalculating the LYs saved, we converted the costs to 1996 dollars, and then recalculated CE ratios. In studies in which incremental CE ratios were calculated for multiple strategies, we recalculated the CE ratio for the strategy recommended by the Guide compared with the strategy that best reflects current practice. Because disaggregated cost and outcome data were not available, we did not attempt to adjust discount rates in published studies to the recommended 3%.<sup>7</sup>

Eight of the nine studies used a 5% discount rate; the exercise counseling study used a 3% rate.

### Calculations

Once the clinical preventive services have been ranked by either LYs or cost effectiveness, the 2 models allocate resources to each CPS based on the total cost to deliver the service to the MCO population. This is a 2-step process. The total number of enrollees who receive the CPS each year is calculated by multiplying the number of enrollees in the target population by the percent that receive the service. This figure is multiplied by the cost of the CPS per enrollee to calculate the total annual cost for each service for the MCO population. This figure is also used in Model I to calculate the total LYs saved in the MCO population.

## ... RESULTS ...

The allocation results for the 2 models (Table 3) illustrate that for identical budgets, the 2 models may yield different results. When the hypothetical MCO set an annual budget of \$600,000 (an average of \$6.00 per enrollee per year) for clinical preventive services, the optimization model selected 4 prevention activities—tuberculin (TB) screening, exercise counseling, influenza vaccination, and cervical cancer screening—which resulted in 4435 LYs saved at a total cost of \$583,300. For the same budget, the CE ranking model selected a different mix of 6 prevention activities—HIV screening, TB screening, exercise counseling, influenza vaccination, smoking counseling, and hepatitis B screening—which resulted in 4220 LYs saved at a total cost of \$534,300.

Clinical preventive service mixes for different budgets are shown in Table 4. The mix of preventive services, the total outcome, and cost vary in each model. For some budgets, the optimal mix of these variables is the same in both models and different for other budgets. If the budget is \$400,000, the selected mix of variables is identical in both models, resulting in the same total outcome for the same cost. If the budget is \$200,000, \$600,000, \$800,000, \$1,000,000 or \$1,200,000, the mix of variables in the 2 models differs; in each case, the total number of LYs saved is higher in the optimization model than in the cost-effectiveness model.

For both models, the clinical preventive services that were selected first were ones that were highly targeted, very effective in saving life years, or had

high compliance rates. The highest ranked services in the cost-effectiveness model were also influenced by the cost of the service and the degree to which it prevents medical costs as reflected in the numerator of the CE ratio.

... DISCUSSION ...

When resources are limited, it is incumbent on organizations to use them wisely and to understand the consequences of those limitations for future decision making. Resources are always being allocated. For example, time spent counseling adolescents about sexual behaviors may limit the time to discuss driving or alcohol use. The models described here allow us to examine the relationship between

economic costs and health outcomes. Good models should enable us to understand how changes in the use of financial resources can lead to different health consequences and facilitate informed decision making about the wisdom of increasing (or decreasing) healthcare spending.

The objective of this study was to demonstrate the use of 2 types of resource allocation models. For several reasons, the results must be considered hypothetical and, therefore, should be interpreted with caution. Many interventions could not be included in the models because of the lack of studies that met our inclusion criteria. The assumptions and conditions in some of the studies we used are unlikely to be replicated in practice and, therefore, lead to erroneous impressions. Other widely accepted interventions appear less prominently in these models

**Table 3.** Results of Two Resource Allocation Models for a Fixed Budget of \$600,000

Clinical Preventive Service (CPS)	Cost-effectiveness Ratio (Net Cost per LYs saved)	Total LYs Saved	Total annual CPS Cost (in 1,000 \$)	Model I*: CPS Selected† (0 or 1)	Model II*: CPS Selected† (0 or 1)	Allocation from Model I* (in 1,000 \$)	Allocation from Model II* (in 1,000 \$)
Human immunodeficiency virus screening	-3281	3.3	38.4	0	1	0	38.4
Tuberculin infection screening	-473	14.4	18	1	1	18	18
Physical activity counseling	2323	3538.0	247.6	1	1	247.6	247.6
Influenza A immunization	2973	584.6	55.6	1	1	55.6	55.6
Tobacco use counseling	14,838	135.1	131.6	0	1	0	131.6
Colorectal cancer screening	18,715	85.6	175.3	0	0	0	0
Cervical cancer screening	22,104	298.3	262.1	1	0	262.1	0
Breast cancer screening	46,987	126.6	302.8	0	0	0	0
Hepatitis B screening	65,049	2.2	43.1	0	1	0	43.1
<b>Budget Constraint</b>	<b>\$600,000</b>						
	<b>Total outcome</b>	<b>Total cost</b>					
Model I (Optimal package)	4435.3	583.3					
Model II (CE package)	4220.2	534.3					

\*Maximize life years saved. LY = life year.

†0 = not selected; 1 = selected.

\*Rank order of most to least cost-effective.

... RESOURCE UTILIZATION ...

than expected. For example, mammography screening fares poorly at low expenditure levels in large part because of its cost effectiveness compared with other interventions. Ideally, the presentation of results would include the findings from sensitivity analyses on the model inputs. We have chosen not to include sensitivity analyses in this study because of the hypothetical nature of the models and the concern that such results would be misleading.

The 2 resource allocation models take different perspectives. The cost-effectiveness model takes the societal perspective, the gold standard for comparing costs and outcomes.<sup>7,19,20</sup> It includes all of the costs and health outcomes associated with the prevention and treatment of a particular disease. Not only is this model comprehensive, it also takes a

long-term perspective. Thus, the model attempts to consider efficiency in healthcare spending in future years. However, resource allocation decisions frequently are made from other perspectives. Employers are interested in their premium costs and the health of their employees, particularly in relation to their productivity and work loss. Because of the highly competitive, price-sensitive marketplace, payers may be concerned more about short-term expenditures because long-term benefits may accrue to other organizations as a result of high turnovers in plan membership. The optimization model takes this more limited, short-term perspective. Only the health outcome (life years saved) and the annual cost of the prevention service are considered. As a consequence, the choices made by the

**Table 4.** Allocation Results from Model I and Model II

Clinical Preventive Service (CPS)	Model I*						Model II†					
	Budget Level (in 1,000 \$)						Budget Level (in 1,000 \$)					
	200	400	600	800	1000	1200	200	400	600	800	1000	1200
Human immunodeficiency virus screening		1		1			1	1	1	1	1	1
Tuberculin infection screening		1	1	1		1	1	1	1	1	1	1
Physical activity counseling		1	1	1	1	1		1	1	1	1	1
Influenza A immunization	1	1	1	1	1	1	1	1	1	1	1	1
Tobacco use counseling	1			1	1	1			1	1	1	1
Colorectal cancer screening						1			1	1	1	1
Cervical cancer screening			1	1	1	1					1	1
Breast cancer screening					1	1						
Hepatitis B screening				1			1		1	1	1	1
Life years saved	719.7	4140.3	4435.3	4575.9	4682.6	4782.6	604.5	4140.3	4220.2	4363.2	4661.5	4661.5

\*Maximize life years saved. LY = life year.

†Rank order of most to least cost effective.

optimization model may actually precipitate a greater increase in the overall budget for the MCO in future years and health expenditures in general than the cost-effectiveness model. It is possible that over time, the cost-effectiveness model may lead to higher levels of population health because of the greater availability of financial health resources.

The 2 models highlight the consequences of these different perspectives. When limited resources are allocated for prevention, the cost-effectiveness model selects the 2 most targeted services, those for pregnant women, reaching less than 2% of the enrolled population. The optimization model selects services that reach a broader segment of the enrolled population (18% or greater)—smokers and persons over 65 years of age. This is because the cost-effectiveness model considers the future costs of HIV- and hepatitis B-infected children compared with the costs of lung cancer and influenza, but the optimization model does not. However, when the prevention budget is relaxed, the results of the 2 models converge. Although these models are hypothetical, it is interesting to note that only at the higher budget levels we examined do the 2 models include most of the clinical preventive services that are currently considered part of today's standard of care. This may give some indication of the financial requirements necessary to provide efficient and quality preventive care to an MCO population.

A number of significant limitations are inherent in the cost-effectiveness model. The model selects a CPS in its entirety (ie, for the entire eligible population) or not at all. Because sufficient resources may be unavailable to fund the next most cost-effective intervention in its entirety, it may be excluded. The resources may be allocated to a less expensive, but less cost-effective service. The consequence is potential cost inefficiency. This limitation is a consequence of using average cost-effectiveness ratios reported in the study analyses we examined. The cost effectiveness of each CPS varies by healthcare-seeking behavior of the target population and the mode of service delivery. For instance, the cost effectiveness of mammography for the women who will seek annual examinations is likely much less than for women who receive them every other year, every third year, or only after intensive outreach efforts to improve delivery rates. Thus the point estimates used in this model are a poor approximation of the marginal cost effectiveness that exists in practice. Availability of true marginal cost-effectiveness estimates for all preventive services would enable development of models that reflect the best use of

each available dollar based on the level of each service and the additional cost and benefit from each service rather than through a monolithic all-or-none approach.

The optimization model allows greater flexibility than does the cost-effectiveness model. For example, the likely pattern of mammography use (eg, annually or biennially) can be incorporated in the models. Constraints can be added as well. Legal, distributional, and other requirements can be incorporated. The model presented here is based on costs expended for care delivery for a 1-year period and does not include long-term benefits of averting future disease-related costs. This is consistent with decision processes for which short-term budget decisions are imperative but neglects to consider societal and long-term medical benefits. Although the model can maximize health outcomes, it does not maximize cost effectiveness.

Variations on these models can be used to assess the value of various allocation decisions using different constraints and assumptions. The primary limitation is the paucity of consistent data on effectiveness, costs, and cost effectiveness. Recent efforts<sup>7,19,20</sup> have been initiated to standardize the methodology, but most studies need to be adapted to costs and risk profiles of the populations under study. For many services, we are fortunate if we have good average cost-effectiveness data. More refined analyses await the availability of more precise estimates of costs and benefits at each level of intervention (ie, the marginal or incremental cost effectiveness) for specific populations and risk groups. These estimates, for example, might demonstrate that rather than increasing influenza vaccine coverage for persons greater than 65 years of age from 95% to 100%, the same resources could be better used by providing directly observed therapy for TB to 70% rather than 40% of persons on anti-TB therapy.

In addition, these models can help decision-makers understand the implications of decisions because their use can highlight distributional, feasibility, or ethical issues. The models' usefulness depends on the validity of the underlying assumptions. Consensus is needed about the costs and benefits to be included: are they to be short-term only or long-term? The former will represent costs of preventive services and relatively few of the benefits (eg, health benefits); the latter can be more inclusive. Should only short-term costs be considered or should long-term benefits of averting future medical treatment costs be considered as well? Costs fre-

quently are the concern of payers, while benefits accrue to payers as well as patients, their families, and employers. Whose perspective is most appropriate: the payer, society, the provider, or all of these? Because models based on differing perspectives and costs yield different results, the objectives and methods of resource allocation need to be well understood and consistent. The models are ultimately dependent on the quality, consistency, and completeness of the data incorporated. Currently, the paucity of consistent data on marginal cost effectiveness limits the allocation decisions to crude "all or none" decisions. Much more complete production functions are required before the value of the models can be fully realized.

We have demonstrated that resource allocation models have the potential for assisting policy makers to select clinical preventive services that will maximize the public's health. Indeed, the use of such models should be considered for guiding the selection of all health services—preventive, diagnostic, and therapeutic. However, before this step can be taken, more complete economic evaluations are needed. Perhaps it is time to require that cost-effectiveness analyses accompany all new preventive, diagnostic, and therapeutic guidelines and that these cost-effectiveness analyses follow the format recommended by the Panel on Cost Effectiveness in Health and Medicine.<sup>7</sup> Certainly advocates for new guidelines would be better served if those guidelines provide necessary information on economic efficiency as well as safety and effectiveness. As pressures to control healthcare costs and provide quality healthcare increase, comprehensive information and resource allocation tools will allow health policy makers to make better and more informed choices.

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