

Dissecting Cost-effectiveness Analysis for Preventive Interventions: A Guide for Decision Makers

Steven M. Teutsch, MD, MPH; and James F. Murray, PhD

Abstract

Background: Decision makers usually limit their use of economic evaluations of preventive interventions to the cost-effectiveness ratio.

Objective: To show decision makers how economic evaluations can be used to understand the cost-effectiveness of different options for altering health intervention strategies.

Observations: Cost-effectiveness analysis provides insights into many factors that contribute to the overall benefits, hazards, and costs of interventions. This article reviews how epidemiologic and intervention characteristics, costs, natural history, targeting, and current interventions influence the value of prevention strategies.

Conclusion: Understanding the factors that contribute to the overall costs and effectiveness of interventions should allow decision makers to better adapt interventions to their needs.

(*Am J Managed Care* 1999;5:000-000)

Preventive services often are touted as cost saving; however, from a societal perspective, relatively few are. With notable exceptions (eg, many immunizations), most incur a net cost. However, cost is not the only factor in making an informed decision. A decision maker should incorporate both the cost and the effectiveness (ie, life-saving potential, improved quality of life) of a service when considering its adoption and translation into

practice. Preventive services have a wide range of cost-effectiveness—from cost and life saving to hundreds of thousands of dollars spent for each life-year saved.¹ This range of cost-effectiveness results for preventive services is affected by certain characteristics that may not be readily apparent or often considered by decision makers.

Although the cost-effectiveness of each preventive strategy should be assessed by using current standards for economic evaluation,^{2,3} the factors considered here should provide insight into how the characteristics of both the disease and the intervention strategy (eg, selecting the appropriate population) can contribute to the relative value of the intervention. An understanding of how these characteristics influence cost-effectiveness may facilitate the targeting of a population and structuring of interventions to provide better value.

Definition of Cost-effectiveness

Cost-effectiveness is calculated as follows: Net Cost/Health Outcomes Achieved, where net cost = cost of intervention + cost of side effects of intervention – cost of disease averted – lost productivity costs.

For contemporary cost-effectiveness studies, the outcome should be measured in terms of health (eg, quality-adjusted life-years, years of life saved). Costs include direct medical and nonmedical (eg, time, transportation, caregiver) costs and, in some situations, productivity costs.

Characteristics of the Disease

The natural history of the disease or injury often provides the motivation for developing a prevention strategy. Diseases that are frequent and have severe, long-term outcomes are more obvious candidates for prevention than those that are less frequent, mild, and short term (Table 1). Thus, prevention of myocardial infarctions or motor vehicle crashes and their attendant morbidity and mortality is likely to be more cost-effective than the prevention of less serious conditions.

From Outcomes Research and Management, US Human Health, Merck & Co., Inc., West Point, PA. At the time the paper was written, S.M.T. was with the Division of Prevention Research and Analytic Methods, Epidemiology Program Office, Centers for Disease Control and Prevention, Atlanta, GA.

Address correspondence to: Steven Teutsch, MD, MPH, Merck & Co, Inc., WP 39-169, PA 19486-0004. E-mail: steven_teutsch@merck.com.

In addition to the severity of the disease outcome, the frequency of the disease among those at risk must be considered. The attributable risk assesses the amount of a disease or injury that is associated with a specific risk factor. The higher the attributable risk, the greater the potential reduction in an adverse health outcome if the risk factor can be eliminated or reduced. For example, early contraceptives had a very high relative risk for stroke, yet the actual risk of stroke was very low among young women taking contraceptives. The risk of pregnancy was high, and the use of contraceptives dramatically reduced that risk and the risk of morbidity associated with pregnancy. Based on the attributable

risks, the risk of stroke was much smaller than the risks associated with pregnancy.

Even when homozygotes can be identified for a genetic disease, persons apparently at the highest risk may have modest rates of severe disease. For example, those who are homozygous for hemochromatosis, a well-defined genetic disease, have a less than 50% probability of having clinically significant disease.⁴

People's preference to delay costs and adverse outcomes is called time preference. To account for this preference, most economic evaluations discount future costs and benefits. Thus, interventions that target outcomes in the near term (eg, influenza vaccination) will be more cost-effective than those that target outcomes long in the future (eg, radon screening and mitigation to prevent lung cancer).

Table 1. Attributes of Cost-effective Preventive Intervention Strategies

<p>Natural History of the Disease or Injury</p> <ul style="list-style-type: none"> Health outcome is frequent Health outcome is severe and/or of long duration Time interval between the intervention and the improvement in the health outcome is short <p>Characteristics of Intervention</p> <ul style="list-style-type: none"> A large proportion of the health outcome is reduced Service needs to be given once or infrequently Intervention is given to the population as a whole rather than one person at a time Those at greatest risk are targeted Intervention is safe Compliance is high For screening tests, intervention has high sensitivity and specificity <p>Characteristics of the Population</p> <ul style="list-style-type: none"> A high-risk or particularly severely affected target population can be identified <p>Cost of the Disease</p> <ul style="list-style-type: none"> The disease is costly to individuals, employers, and society <p>Cost of the Intervention</p> <ul style="list-style-type: none"> Cost of the preventive service and program is low Cost does not induce other costs <p>Current Level of Intervention</p> <ul style="list-style-type: none"> The current use of the intervention can be significantly increased. <p>Other Considerations</p> <ul style="list-style-type: none"> The intervention has secondary benefits

Characteristics of the Intervention

Interventions differ substantially in effectiveness because of differences in efficacy, the number of interactions required, and the ease with which the interventions can be administered and targeted. The more efficacious the intervention, the higher the likely payoffs. Many vaccines can reduce the risk for disease by almost 100%, whereas other interventions are much less efficacious; mammography reduces breast cancer mortality by less than 30% even among women 50 to 69 years of age, the group for whom the benefits have been most clearly established.⁵ Preventive services that can be delivered fully in a single visit are likely to be more cost-effective than those that require repeated applications over extended periods of time. Vaccines can be administered once, or a few times over a lifetime, whereas some screening measures for cancer (eg, mammography, tests for fecal occult blood) require regular, repeated screening to achieve the full measure of their benefits. An intervention that can be administered on a population-wide basis (eg, fluoridating water, reducing lead in gasoline) is likely to be more cost-effective than an intervention administered on an individual basis (eg, screening children for blood lead levels and mitigating their homes). Conversely, those interventions that can be targeted to a subgroup of the population at particularly high risk may be more cost-effective than those for which high-risk groups cannot be identified readily. A recent study demonstrated that universal infant screening for sickle cell disease in Alaska would cost more than \$2 million per death averted, whereas screening targeted to black infants with selective fol-

low-up would cost approximately \$200,000 per death averted.⁶

Interventions also can induce costs (see Cost of the Intervention, below). Some cause hazards that might otherwise have been avoided. For example, although fortifying food with folic acid could reduce neural tube defects by 50%,⁷ it could also mask the diagnosis of vitamin B₁₂ deficiency, particularly among the elderly and vegans. Many preventive clinical interventions induce significant costs and require care and follow-up of many people, even though the disease or injury might occur in only a small number of persons. The very success of vaccination has reduced the risk of many childhood diseases to the point that measles and polio are rare events regardless of immunization status. Men who screen positive for prostate-specific antigen may be diagnosed with prostate cancer and treated, although many might never have progressed to clinically important disease. Even population-based interventions often induce time and other costs for many persons in the population who would never incur the disease. School-based education programs to prevent skin cancer, in addition to potentially reducing cancer, take time from other activities and stimulate people to purchase hats and ultraviolet-protective products.

Interventions for which there is high compliance (eg, that more than 95% of children are immunized with required antigens by school entry⁸) are likely to be more cost-effective than those for which compliance is low (eg, only 13% of students in grades 9-12 followed recommendations to eat five vegetables per day⁹), because fewer resources are required to ensure adherence. Resources that are required to improve adherence to regimens also will reduce the relative cost-effectiveness.

The cost-effectiveness of screening tests is highly dependent on the sensitivity (the ability of a test to detect all those with the condition) and specificity (the ability of a test to correctly identify those without the condition) of the screening test itself. Poor sensitivity leads to low effectiveness because of failure to identify those who would benefit from follow-up, and poor specificity leads to unnecessary follow-up and testing (induced costs) of those who do not have the disease.

Screening programs represent a special set of interventions based on conditions for which there is a long latency between detectability of disease and the health outcome, as well as an effective intervention to reduce the risk for or the severity of the disease. Screening tests that have both high sensitivity

and specificity maximize disease detection and minimize induced costs from follow-up of false-positive results. As the effectiveness of the treatment or intervention improves, the value of screening improves as well.

Characteristics of the Population

Interventions often are initially targeted to high-risk or more severely diseased individuals. The marginal cost-effectiveness of expanding such interventions more broadly may be less attractive because the costs increase and/or the benefits decrease, compared with what was observed in the higher risk group. As the program targets lower risk, less severely affected individuals, its cost-effectiveness may decrease.

Many of the factors discussed here in the context of the characteristics of the disease or the intervention can be viewed from a population perspective. For example, from an individual perspective, mammography screening of women with no risk factors before age 50 will likely benefit a number of women. Individuals may be quite willing to take the time, pay the costs, and have the procedures for benign lesions to potentially reduce their risk of breast cancer mortality. However, from a population perspective, the overall balance of benefits and harms makes resource allocation for this intervention less attractive than it would be for other potential interventions. Thus, the population perspective can be helpful to guide decision makers in choosing who to target for a service.

Cost of the Disease

In a cost-effectiveness analysis, the numerator consists of the net cost of the prevention strategy and the cost of the disease averted. The cost of the disease averted usually is based on the direct medical and nonmedical costs, and, sometimes, the productivity costs. Thus, conditions that are more costly and cause loss of time at work or other activity will be associated with greater cost-effectiveness. For example, varicella vaccine can reduce the number of potential cases by 94%; it is cost-saving when one considers the productivity gained from parents who do not need to miss work to care for a child with varicella.¹⁰

Cost of the Intervention

The cost of the intervention should be considered at 2 levels. The first is the cost of the individual-level services, if any are provided. The individual cost of advising a patient who smokes to choose a quit date

is inexpensive, whereas screening of asymptomatic persons for coronary artery disease may be associated with prohibitive costs. In the aggregate, however, the total costs of even relatively inexpensive interventions can be quite high when individual services are summed across an entire population. The total management and implementation costs for a program must always be considered. These costs are frequently underestimated by public health programs because financial systems do not readily allow them to capture all program costs (eg, rent, utilities, personnel time, materials).

Induced costs may be a substantial portion of the actual cost of interventions. These costs are those caused by the prevention program that would not otherwise have been incurred. For example, follow-up biopsies for women who have false-positive mammograms may represent up to 85% of the cost of these services. Because these women do not have breast cancer, many of these costs might never have been incurred or been incurred much later when a mass was detected without a population-based mammography screening program.

Current Level of Intervention

Most economic evaluations are conducted by comparing an intervention strategy with doing nothing. Yet in most cases, there is some existing delivery of the prevention service. A marginal cost-effectiveness analysis that measures changes in outcomes against the changes in cost compared with the existing level of the prevention program provides better information with which to determine the value of changing the intensity of a preventive service. For example, given 95% coverage of vaccination for children at the time of school entry,⁸ what are the additional costs and additional benefits of achieving 95% coverage by age 2 years? For many services, the marginal cost-effectiveness may be poor at low levels of activity because of start-up costs; then it improves as the services become more routine and achieve widespread acceptance. It often is extremely costly to reach the last individuals because additional outreach, low compliance, and other components tend to reduce the cost-effectiveness. Thus, the cost-effectiveness of an intervention is often greatest when its use is low or modest, and least when its use is extremely high.

Secondary Benefits

For many interventions, the individual who receives the preventive service receives most of the

benefits. For some interventions, however, there may be significant secondary benefits. For infectious diseases, prevention of exposures and reduction in cases reduce secondary transmission. For example, prompt recognition of contaminated food protects not only the group that has the food but has not consumed it, but also additional persons who might have purchased contaminated food from the same source had action not been taken. Vaccinations can provide herd immunity, thus protecting persons who never availed themselves of a vaccine. Disease elimination and eradication programs can provide benefits indefinitely. For eradication, the benefits can occur at virtually no subsequent cost. Similarly, environmental interventions, such as eliminating lead from gasoline or stopping production of hazardous chemicals, may benefit individuals long in the future.

Conclusion

The factors discussed here provide key insights to help decision makers understand the sometimes disparate cost-effectiveness results that are reported for prevention procedures.

Cost-effectiveness analysis is a valuable tool for allocating scarce resources. Recent efforts to make economic evaluations more comparable will facilitate these efforts.

Cost-effectiveness analyses should not be viewed as static. Decision makers who understand the underlying interventions, costs, benefits, and populations used in a cost-effectiveness analysis can use the baseline analysis as a springboard for developing and adapting intervention strategies appropriate to the populations they serve. For example, the target population might be changed, guidelines might recommend different cut-off points for screening tests to adjust their sensitivity and specificity, or steps might be taken to enhance adherence to recommendations.

However, cost-effectiveness is not the sole factor in making a decision. To make a truly informed decision, a decision maker must consider not only all of the issues discussed here, but also issues related to equity, feasibility, and other social concerns. Cost-effectiveness measures summarize the epidemiologic and economic characteristics of a disease or injury and intervention strategies. An understanding of the factors that enhance the effectiveness and reduce the costs of interventions should help us to design more efficient interventions and to understand the relative cost-effectiveness of those interventions already in place.

Acknowledgment

We would like to thank Anne Haddix, PhD for conceptual development of this paper.

... REFERENCES ...

1. Tengs TZ, Adams ME, Pliskin JS, et al. Five-hundred life-saving interventions and their cost-effectiveness. *Risk Analysis* 1995;15:369-390.
2. Haddix AC, Teutsch SM, Shaffer PA, et al, eds. *Prevention Effectiveness: A Guide to Decision Analysis and Economic Evaluation*. New York, NY: Oxford University Press; 1996.
3. Gold MR, Siegel JE, Russell LB, et al. *Cost-effectiveness in Health and Medicine*. New York, NY: Oxford University Press; 1996.
4. Burke W, Thomson E, Khoury MJ, et al. Hereditary hemochromatosis: Gene discovery and its implications for population-based screening. *JAMA* 1998;280:172-178.
5. US Preventive Services Task Force. *Guide to Clinical Preventive Services*. 2nd ed. Baltimore, MD: Williams & Wilkins; 1996.
6. Gessner BD, Teutsch SM, Shaffer PA. A cost-effectiveness evaluation of newborn hemoglobinopathy screening from the perspective of state health care systems. *Early Hum Dev* 1996;45:257-275.
7. Centers for Disease Control and Prevention. Use of folic acid for prevention of spina bifida and other neural tube defects. *MMWR Morb Mortal Wkly Rep* 1992;41(RR-14):1-7.
8. Centers for Disease Control and Prevention. Retrospective assessment of vaccination coverage among school-aged children—selected US cities, 1991. *MMWR Morb Mortal Wkly Rep* 1992;41:103-107.
9. Centers for Disease Control and Prevention. Selected tobacco-use behaviors and dietary patterns among high school students—United States, 1991. *MMWR Morb Mortal Wkly Rep* 1992;41:417-421.
10. Lieu TA, Cochi SL, Black SB, et al. Cost-effectiveness of a routine varicella vaccine program for US children. *JAMA* 1994;271:375-381.