Application of Economic Analysis to Diabetes and Diabetes Care

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Facing limited resources and increases in demand from competing programs, policymakers and health care providers seek guidance from economic studies on how to use health care resources wisely. Previous economic studies mainly focused on estimating the cost of diabetes and cost-effectiveness of different interventions. These studies found that diabetes is costly and that its cost will continue to increase; thus, more resources should be devoted to research aimed at finding effective means to prevent the disease and its complications. In addition, the cost-effectiveness of interventions varies greatly in terms of quality-adjusted life-years gained; therefore, efficient uses of resources should be an important consideration when interventions are prioritized. The need for economic studies will continue to grow because of increasing demand for limited resources from the growing number of interventions available. Future studies should be of better quality and broadened in areas of research.

Economics is a discipline that studies how people choose to use limited resources to satisfy their unlimited wants so that the gain from the available resources can be maximized. Applying the framework of economics to resource allocation in diabetes prevention and control is important for at least 3 reasons. First, diabetes is costly. In 2002, the United States incurred an estimated $92 billion in direct medical costs, which will increase to $138 billion by 2020 (1). Second, resources that can be devoted to prevention and control of diabetes are limited because of the “opportunity cost” of doing so. Opportunity costs are the value that is forgone by using resources for one activity instead of another. Third, the need for resources will continue to increase because of the increasing prevalence of diabetes and demand for comprehensive care and new treatments.

We describe how economic analyses can inform and guide policy decisions about allocation of resources in the prevention and care of diabetes. We summarize the current status of economic analysis with a focus on 2 general questions: What is the economic cost of diabetes, and what is the cost-effectiveness, or economic return, on interventions used to prevent and control the disease?

To select studies for our analysis, we searched the MEDLINE database for articles published from 1997 to 2003 by using the keywords diabetes mellitus and either cost or cost-effectiveness. We included only studies that met the basic principles of economic evaluations in health and medicine (2–4). For earlier studies, we relied on the results of 2 comprehensive reviews (5, 6) that used similar inclusion criteria. We adjusted all estimates of costs and cost-effectiveness ratios to 2002 U.S. dollars (by using the Consumer Price Index for medical care). When multiple studies evaluated the cost-effectiveness of an intervention, we report the median cost-effectiveness ratio.

Economic Costs of Diabetes

Research Methods

The cost-of-illness method was most often used to estimate the economic cost of diabetes. This method asks, “How much does a disease such as diabetes cost society, including both direct and indirect costs?” Direct economic costs are those generated by treatment of disease, including costs related to hospital care, physician services, long-term care, and pharmacotherapy. In contrast, indirect economic costs are the present and future value of productivity lost to society as a consequence of the disease. Indirect costs are most often estimated from earnings forgone because of illness, disability, and premature death. A third category of costs is related to psychosocial aspects of illness or its effect on quality of life; this type of cost is included only occasionally because of the difficulty of measuring it. Cost-of-illness studies are typically conducted by examining costs among a prevalent sample over a finite period (for example, 1 year) or by examining costs incurred among a cohort of persons with incident cases of the disease over a specific time frame. For this latter approach, costs are often examined from diagnosis to death through the natural progression of the disease, allowing examination of potential savings that can be realized if a case of illness were prevented by implementation of a health program.

What Is the Cost of Diabetes?

Numerous studies have documented the economic costs of diabetes, and several investigators have provided detailed reviews (5). In the United States, the estimated total costs (direct and indirect) of diabetes increased from $23 billion in 1969 to $132 billion in 2002 (1, 5). The total cost could increase to $156 billion by 2010 and to $192 billion by 2020 (1). The increase in estimated costs is primarily due to the increasing prevalence of diabetes (5). In addition, changes in study methods, such as inclusion of more diseases and conditions associated with diabetes over time, also contribute to the estimated increase in costs (5).

Table 1 shows the composition of the estimated total cost of $132 billion in 2002. A person with diabetes spends 2.4 to 2.6 times more in medical costs than does a person without diabetes when differences in demographic characteristics are taken into account. Excess costs per capita differ by age and are highest among younger age groups (5). Additional inpatient hospital costs account for most of the excess costs.
Table 1. Total Economic Cost of Diabetes in the United States in 2002*

| Type of Cost                        | Cost of Diabetes | Proportion of Total Cost† |
|------------------------------------|------------------|---------------------------|
|                                    | Age <45 y | Age 45–64 y | Age ≥65 y | All Ages |
| Direct medical costs               | 12 597     | 31 638       | 47 625    | 91 860    |% |
| Institutional care                 | 7759       | 19 366       | 27 091    | 54 216    |41 |
| Outpatient care                    | 2194       | 5072         | 12 863    | 20 129    |15 |
| Outpatient medication and supplies | 2644       | 7200         | 7671      | 17 515    |13 |
| Indirect costs                     | –          | –            | –         | 39 811    |    |
| Morbidity                          | –          | –            | –         | 18 253    |14 |
| Mortality                          | –          | –            | –         | 21 558    |16 |
| Total                              | –          | –            | –         | 131 671   |100 |

* Data from reference 1. In 2002, an estimated 12.1 million people had diagnosed diabetes and 186 000 deaths were attributable to diabetes.
† Numbers do not add up to 100 because of rounding.

Bagust and colleagues (7) used a simulation model to estimate lifetime medical costs for type 2 diabetes and found that men incurred 1.8 times ($102 300 in 2002 U.S. dollars) and women incurred 1.7 times ($124 300 in 2002 U.S. dollars) higher costs compared with persons without diabetes (7). These estimates include increased medical costs due to the disease and lower health care costs due to a shortened life expectancy.

**Economic Evaluation of Diabetes Interventions**

Research Methods

Economic evaluation of interventions asks whether additional health benefits can be obtained from the same amount of resources or whether the same benefit can be achieved with fewer resources by use of another intervention. The costs and health outcomes of an intervention are normally compared with those of an alternative intervention (usually the current standard of practice).

The 3 primary methods of economic evaluations that are used in health are cost–benefit analysis, cost-effectiveness analysis, and cost–utility analysis (Table 2) (8, 9). In cost–benefit analysis, costs and benefits are converted to monetary units. In contrast, in cost-effectiveness analysis and cost–utility analysis, costs are expressed in monetary units but health benefits are expressed in a natural unit (such as cases of disease) or quality-adjusted life-years (QALYs). Quality-adjusted life-years are a measure of health outcome in which each period of time is assigned a weight ranging from 0 to 1 that corresponds to health-related quality of life during that period. A weight of 1 corresponds to perfect health, and a weight of 0 corresponds to death. The weights are then aggregated across time periods (8).

**What Is Cost-Effectiveness or Return on Interventions for Diabetes?**

Klonoff and Schwartz (6) summarized the status of the cost-effectiveness of 17 widely used interventions for the care of diabetes on the basis of studies published before

Table 2. Three Economic Methods of Evaluating an Intervention in Health and Medicine

| Method              | Monetary Costs Considered | Monetary Benefits Considered | Health Benefits Considered | Overall Summary Measure of Efficiency | Rule for Use of an Intervention | Example of Diabetes Study (Reference) |
|---------------------|---------------------------|------------------------------|---------------------------|--------------------------------------|--------------------------------|-------------------------------------|
| Cost–benefit analysis | Direct medical, direct nonmedical, indirect | Reduction in direct medical, direct nonmedical, and indirect costs | Monetary value of gain in life-years and quality of life | Net benefit = (monetary benefit + health benefits) – monetary costs | Net benefit > 0 | Diabetes self-management (6) |
| Cost-effectiveness analysis | Direct medical, direct nonmedical, indirect costs | Reduction in direct medical, direct nonmedical, and indirect costs | Gain in health, measured in natural units (such as cases of disease avoided) | Cost-effectiveness ratio = (monetary costs – monetary costs)/health gained (e.g., costs per case of diabetes prevented) | Cost-effectiveness ratio less than society is willing to pay | Cost-effectiveness of preventing diabetes (14) |
| Cost–utility analysis | Direct medical, direct nonmedical | Reduction in direct medical and direct nonmedical costs | Gain in health, measured in QALYs | Cost–utility ratio = (monetary costs – QALYs gained) | Cost–utility ratio less than society is willing to pay | Cost–utility of cholesterol control (22) |

* QALY = quality-adjusted life-year.
1998. We updated the results of Klonoff and Schwartz and provided the cost-effectiveness of interventions for prevention and screening of diabetes (Table 3).

**Primary Prevention**

Clinical trials in Sweden, China, Finland, Canada, and the United States have shown that interventions involving diet, physical activity, or certain pharmacotherapies (metformin or acarbose) can reduce the risk for type 2 diabetes by 25% to 58% (10–13). In the Diabetes Prevention Program, a 3-year clinical trial, lifestyle intervention and metformin therapy annually cost approximately $1000 more per participant than did the placebo or standard lifestyle intervention (14). Lifestyle intervention and metformin therapy cost $17,200 and $34,500, respectively, per case of diabetes prevented or delayed, or $34,600 and $109,600 per QALY gained. If the individual intervention used in this study could have been delivered in a group setting at similar levels of effectiveness (17), costs per QALY gained would be $5200. Similarly, if a generic version of metformin rather than the brand-name drug (Glucophage, Bristol-Myers Squibb Co., Princeton, New Jersey) had been used, the cost per QALY gained would decrease to $43,800.

**Secondary Prevention**

The rationale for screening for undiagnosed diabetes is that complications can be prevented or delayed if diabetes is treated before clinical symptoms appear. No clinical trial has examined all of the benefits and costs of screening for diabetes. However, the Centers for Disease Control and Prevention Diabetes Cost-Effectiveness Study Group (15) used a simulation model to examine the lifetime benefits and costs of one-time clinic-based opportunistic screening compared with diagnosis and treatment as it occurs in current clinical practice. Screening and early treatment reduced the lifetime occurrence of kidney failure by 26%, blindness by 35%, and lower-extremity amputation by 22% and yielded a gain of 0.08 QALY. On average, diabetes was diagnosed 5.5 years earlier with the screening program, and the estimated average annual cost for treatment of a newly diagnosed patient was $1300. The intervention would cost $73,500 per QALY gained. Greater benefit and a more favorable cost-effectiveness ratio were found for younger persons and African-American persons than for the general population.

**Tertiary Prevention: Early Detection of Diabetic Complications**

Eye Disease. Annual screening for and subsequent treatment of diabetic retinopathy reduce costs and improve health outcomes (that is, they are cost saving) when the reduction in government payments for disability and rehabilitation is included (6). However, inclusion of all such benefits may not be appropriate because government payments for disability represent an income transfer, not a cost to society. If government payments for blindness are excluded, the intervention would have net positive costs, at a median cost of $33,400 per QALY gained for persons with type 2 diabetes and $5500 per QALY gained for those with type 1 diabetes (6, 16). For the former group, retinopathy screening and treatment programs were more cost-effective

### Table 3. Cost–Utility or Cost–Benefit Ratio of Interventions To Prevent and Treat Diabetes from the Perspective of the Single Payer

| Intervention                                      | Study Population                              | Cost per QALY, $, or Cost–Benefit Ratio | Reference |
|---------------------------------------------------|------------------------------------------------|----------------------------------------|-----------|
| **Primary prevention**                             |                                                |                                        |           |
| Lifestyle intervention                            | Impaired glucose tolerance                    | 34 600                                 | 14        |
| Metformin therapy                                 | Impaired glucose tolerance                    | 109 600                                | 14        |
| **Secondary prevention**                          |                                                |                                        |           |
| One-time opportunistic screening for undiagnosed diabetes | General population                           | 73 500                                 | 15        |
| **Tertiary prevention**                           |                                                |                                        |           |
| Screening for retinopathy                         | Type 1 diabetes                               | 5500                                   | 6         |
|                                                   | Type 2 diabetes                               | 3400                                   | 17        |
| Nephropathy prevention                            |                                                |                                        |           |
| Screening for microalbuminuria                    | Type 1 diabetes                               | 47 400                                 |           |
| Treating all patients with angiotensin-converting enzyme inhibitors | Type 2 diabetes                               | 8800                                   | 6, 20     |
| Foot care program                                 | Type 1 or type 2 diabetes, with various risks of amputation | Cost saving to 7100 | 6, 19     |
| Intensive glucose control                         | Newly diagnosed type 2 diabetes               | 35 300                                 | 6, 22     |
|                                                   | Type 1 diabetes                               | 27 100                                 |           |
| Intensive blood pressure control                  | Newly diagnosed type 2 diabetes               | 2400                                   | 22        |
| Cholesterol control                               | Newly diagnosed type 2 diabetes               | 63 200                                 | 22        |
| Smoking cessation                                 | Newly diagnosed type 2 diabetes               | 12 500                                 | 24        |
| Self-management                                   | Type 1 or type 2 diabetes                     | 1:2.0                                  | 6         |
| Preconception care                                | Women within reproductive ages with type 1 or type 2 diabetes | 1:3.5                                 | 6         |

*QALY = quality-adjusted life-year.*
among persons who require insulin (6). Screening and treatment programs were also more cost-effective among older persons and those with poor glycemic control (6, 16, 17).

Using a Markov model to examine screening intervals for eye disease among persons with type 2 diabetes, Vijan and associates (16) found that using annual screening rather than screening every other year cost $130 900 per additional QALY gained, whereas screening every 2 years rather than every 3 years cost $60 700 per additional QALY gained. Because annual screening offers little marginal benefit over screening every other year in terms of QALYs, the more frequent schedule may not be warranted, particularly for persons at low risk (for example, those with good glycemic control, younger age, and no retinopathy on previous examination). This study did not consider other benefits of retinopathy screening, such as diagnosis of other vision disorders.

Foot Disease. Foot infection and ulcers are serious complications of diabetes, and several preventive interventions are effective: education of patients and professionals on foot care, access to appropriate footwear, and multidisciplinary clinics (18). Over 3 years, the potential economic benefit of each of these strategies in reducing the risk for amputation among persons with diabetes and a history of foot ulcers ranged from $3600 to $5600; the highest benefit was seen with educational interventions (18). The study did not include the costs of the interventions, but because the cost per person for any of the interventions is likely to be less than $3600 per person over 3 years, all interventions could be cost saving.

Researchers conducted a cost–utility analysis to assess an intensive intervention for preventing diabetes-related foot ulcers and amputation as recommended by the International Working Group on Foot Care (19). This group recommends that patients receive tailored education on foot care and that those who are at higher risk receive additional physician visits and appropriate footwear (19). Within the 5-year study period, the recommended interventions produced no significant health benefits for persons without specific risk factors compared with those receiving current usual care in Sweden. Among persons at risk for foot ulcers, the recommended intervention was cost saving or cost approximately $7100 per QALY, depending on risk level. The greatest benefit was achieved for persons at highest risk (those with at least 1 previous foot ulcer or amputation).

Kidney Disease. Screening for early renal disease followed by appropriate treatment can slow the disease progression and prevent or delay end-stage renal disease. Among persons with type 1 diabetes, screening for microalbuminuria and treatment of those who test positive with angiotensin-converting enzyme inhibitors would cost $47 400 per QALY (6). Golan and colleagues (20) evaluated the cost-effectiveness of 3 strategies for prevention of end-stage renal disease in persons with type 2 diabetes. In all cases, treatment with angiotensin-converting enzyme inhibitors was given. Two strategies involved screening for microalbuminuria and for gross proteinuria; those who tested positive were treated. In the third strategy, all patients were treated. Screening for gross proteinuria had the highest cost and the lowest benefit and thus should not be used. Treating all patients was more expensive than screening for microalbuminuria, but it also yielded more health benefits. The cost for 1 additional QALY gained by treating all persons with angiotensin-converting enzyme inhibitors rather than screening for and treating with microalbuminuria was $8800, but the universal treatment became less cost-effective with older age at diagnosis. Considering its simplicity, the likelihood of higher adherence by clinicians, and the ability to provide additional benefit at modest additional cost, treatment of all diabetic persons with angiotensin-converting enzyme inhibitors might be a better strategy than screening for microalbuminuria, particularly among middle-aged adults.

Intensive Glucose Control. The Diabetes Control and Complications Research Group (21) evaluated the cost-effectiveness of intensive glycemic control for persons with type 1 diabetes (Table 3). The intensive control applied for a lifetime to approximately 120 000 patients with type 1 diabetes in the United States would result in a gain of 920 000 years of sight, 691 000 years free of end-stage renal disease, 678 000 years free of lower-extremity amputation, and 611 000 years of life at a cost of $5.2 billion above that for conventional care over the lifetime of the population. The intervention would cost $27 100 per QALY gained.

A computer simulation model was used to evaluate the cost-effectiveness of intensive glucose control with the goal of normoglycemia in persons with newly diagnosed type 2 diabetes in the United States (22, 23). Intensive glucose control with drug therapies (compared with conventional care) over a lifetime would cost $35 300 per QALY gained. Intensive glucose control was more cost-effective among younger persons (22).

Treatment of Cardiovascular Disease and Risk Reduction. Several interventions, including pharmacotherapy for controlling blood pressure and cholesterol values; aspirin; and behavioral interventions such as diet, physical activity, and cessation of smoking, can reduce the risk for cardiovascular disease among persons with diabetes. Using a simulation model, the Centers for Disease Control and Prevention Diabetes Cost-Effectiveness Study Group evaluated the cost-effectiveness of intensive control of blood pressure, control of total cholesterol level, and cessation of smoking over the lifetime of a person with newly diagnosed diabetes (24) (Table 3). Intensive control of blood pressure would reduce costs and improve health outcomes, thus making it a cost-saving intervention. Cessation of smoking cost $12 500 per QALY gained, and a cholesterol-lowering intervention cost $63 200 per QALY gained. Control of cholesterol level is less cost-effective among the younger persons (those 25 to 34 years of age) or very old persons (those 85 to 94 years of age).
Self-Management. Several economic studies have evaluated the effect of self-management on diabetes-related hospital costs (6). A diabetes self-management program normally involves teaching a completed self-care curriculum in a variety of settings, including outpatient centers, patient homes, or clinics. The cost of providing such a program was compared with hospital costs over the subsequent year with and without the program. For each dollar invested in the self-management program, the median reduction in hospital costs was $2. This result underestimated the true benefit of the program, since both quality of life and reduction in long-term health care costs were excluded.

Preconception Care. Preconception care for women with diagnosed diabetes reduces the incidence of fetal malformation and spontaneous abortion. Klonoff and Schwartz reviewed the study that evaluated the effect of adding patient education and intensive glycemic control to a standard prenatal care program (6). For every $1 invested in such program, the initial hospital costs for mother and infant would be reduced by $3.50. The return on such an investment would be much higher if the long-term economic benefit of preventing malformed offspring were included.

DISCUSSION

Since the 1970s, much progress has been made in applying economic analysis to diabetes and diabetes care. The number of published studies increased from an average of 2 articles per year in 1979–1980 to an average of 20 per year in 1999–2000 (25). The scope of research has also expanded from cost-of-illness studies to areas such as economic evaluations of interventions (25).

Cost-of-illness studies have documented that diabetes is costly and that this cost will continue to increase; thus, more resources should be devoted to finding effective means to prevent the disease and its complications. Cost-of-illness estimates can provide valuable data for informing and educating policymakers about how much health care resources are consumed. These estimates, however, do not represent the amount of money that society can save if diabetes is eradicated, because interventions used to prevent diabetes are not 100% effective and are not free.

A more important question for health care providers and policymakers is how to allocate health care resources to get most the gain on investment. Cost–benefit analysis, cost-effectiveness analysis, and cost–utility analysis address this question. For cost–benefit analysis, an intervention should be used if its benefit exceeds its cost or its cost–benefit ratio is greater than 1 (Table 2). For cost-effectiveness analysis and cost–utility analysis, an intervention should be used if society’s willingness to pay for the health outcome exceeds the cost-effectiveness ratio (or cost–utility ratio) (Table 2). For example, if the intervention costs $40 000 to produce 1 QALY, it should be used if society is willing to pay more than $40 000 per QALY. However, society’s willingness to pay for a health outcome appears to vary by intervention, which makes resource decision making based on cost-effectiveness ratios alone very difficult. For example, society may prefer interventions that have large individual benefits or are targeted at very ill patients over those that have small individual benefits or are targeted at relatively healthy patients. Correspondingly, there is no universally accepted threshold of cost per QALY that can be used to determine whether an intervention should be adopted (26). The general rule of using cost-effectiveness analysis or cost–utility analysis data to guide the decision about resource allocation is to give priority to interventions that have a better “value.” Within a given amount of health care resources, cost-saving interventions, such as intensive blood pressure control, should always be applied first, followed by interventions with lower cost-effectiveness ratios.

Demand for economic research will continue to increase because of the need to assess the growing number of interventions available to prevent and treat diabetes. Because of difference in study methods (5, 6), results of many previous studies are difficult to compare. Future cost and cost-effectiveness studies should use standard methods (8, 27). In addition, future economic studies should continue to expand the scope of research. For example, economic analysis can examine how such economic factors as level of income and education, lifestyle selection, food purchase and consumption behaviors, health insurance status, and ability to access health care are associated with development of diabetes and its complications. Economic analysis can also study financial incentives or disincentives that can be used to prevent diabetes and obesity. Research should focus on the role that financial incentives play in designing an effective intervention and should not be just an afterthought to understanding how and why interventions take place.

Economic studies demonstrate that diabetes is a very costly disease and that interventions used to prevent and control diabetes may differ greatly in terms of costs per health outcome gained. Health providers and policymakers should use this information in making clinical and policy decisions in order to use resources efficiently. Efforts are needed to improve the quality of economic studies and to expand economic research to new areas in the future. Economic assessments of new technologies should continue to ensure that new treatments or interventions add value. In addition, economic assessment studies should be based on standard research methods and reliable data to ensure validity and comparability of results. Finally, areas of economic research should be broadened, such as studying issues related to prevention of diabetes.

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