

Improving Health: Measuring Effects of Medical Care

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WITHIN THIS CENTURY, AVERAGE LIFE EXPECTANCY has increased from approximately 45 to 75 years for citizens of industrial countries, an improvement assumed by many to be largely the result of advances in the content and distribution of medical care. This assumption has been called into question by a number of observers, however (Carlson 1975; Illich 1976; McKinlay and McKinlay 1977; McKeown 1979); others have argued for the good medicine does, in most instances unsupported by measurements of benefits (McDermott 1978; Beeson 1980; Levine, Feldman, and Elinson 1983; Anderson and Morrison 1989) and, in one instance, reporting that lower regional death rates were associated with higher Medicare expenditures (Hadley 1982). Today most observers would agree that the causes of increased longevity are several, including improvements in nutrition, housing, sanitation, occupational hazards, and lifestyle, in addition to medical care. In order to identify the separate contribution of medical care, we have chosen to estimate the contributions of individual medical interventions to life expectancy and quality of life, and from these to create an inventory of the benefits to health of medical care.

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Estimates of changes in life expectancy were made possible by the wealth of condition-specific mortality data and their changes over time, which have become available primarily from the National Center for Health Statistics, and by the rapidly growing body of evidence regarding the efficacy of clinical preventive and curative interventions.

The conditions for analysis were chosen on the following basis: For the life expectancy analyses, we have chosen conditions that fulfilled all three of the following criteria:

1. Death rates for the condition have fallen (National Center for Health Statistics 1992).
2. Relevant treatment has been shown, usually in randomized clinical trials, to be efficacious.
3. The prevalence of the condition, together with the first two criteria, creates a notable impact on life expectancy when the effect is spread across the entire U.S. population.

Developing estimates of the effects of medical care on quality of life is more difficult than calculating their impact on life expectancy. For our present purposes, we take quality of life to be roughly the same as the state captured by the terms "health status" and "well-being." The difficulty in measuring the effects of medical care on quality of life persists despite improvements in definitions, the development of measuring instruments directed at both generic and condition-specific attributes of quality of life, and an enlarging base of relevant data. We focus attention on quality of life because increasingly medical care is sought and delivered in the expectation that it will improve not life expectancy, but rather the quality of that life. The conditions to evaluate were chosen primarily from the most recent estimates in the National Health Interview Survey listing of chronic conditions (Adams and Benson 1991); they were selected on the basis of incidence and prevalence, and of efficacious treatment, the evidence for which was strong but usually not based on randomized trials.

By organizing outcomes in this way, we have developed an inventory of medical services that are currently provided in an industrial country and that make a large contribution to life expectancy and offer much to the quality of life of the population. Our purpose is to inform decision makers of outcomes that have been achieved. The inventory also identi-

fies health-related problems amenable to additional gains on the basis of present knowledge.

Accuracy of Life Expectancy and Quality-of-Life Calculations

Several approaches were used to estimate gains in life expectancy. The reader who is primarily concerned with the results does not necessarily want to know all about the methods, important though they might be. Consequently, for the interested reader, we discuss the methods and some of their limitations in an appendix.

Some discussion may be helpful about our intent and the accuracy of the results we provide on extension of life, number of people involved, and benefits received by the population. The reader will appreciate that estimating the number of people affected by a disease or symptom already has many uncertainties. Diagnoses can be mistaken and methods of gathering data are often inadequate in spite of decades of effort, national and international, to improve such statistics. Similar issues confuse information about relief of symptoms, cure of disease, and cause of death. When we produce the numbers of people benefiting from procedures, we must combine these uncertain figures in ways that are bound to lead to considerable uncertainty in the final numbers. It will help if the reader keeps in mind that we are trying to produce rough approximations for the U.S. population affected favorably by specific medical services.

We are especially sensitive to the point that at some stage in many assessments we have to estimate—guess—the fraction of an improvement or benefit that emerges from various changes in society, as opposed to that achieved by medical care. These choices have been made as best guesses, not as conservative or liberal estimates, and other students, differently informed, might make substantially different estimates. Best guess may not mean good guess, and so the reader then may want to think how interpretations might change if the findings were altered in either direction by 10 or 20 percent. Such uncertainties seem to be inherent in this kind of work.

We have not tried to develop formal methods of assessing uncertainty in our estimates, but we are familiar with unpublished evidence (Alpert

and Raiffa 1969) showing that people who make these kinds of estimates are usually much too confident about their accuracy.

The Role of Medical Care in Extending Life: Clinical Preventive Services

Our plan is to present a few examples of treatments or procedures so that the reader can appreciate how we went about the work, and then to illustrate in tabular form the results of similar efforts on other diseases or conditions. Space limitations preclude full treatment of each disease or procedure here. A more complete description appears elsewhere (Bunker, Frazier, and Mosteller 1994).

The U.S. Preventive Services Task Force (1989), in its report to the Secretary of Health and Human Services entitled *Guide to Clinical Preventive Services*, reviewed the evidence for the efficacy of screening for 47 medical conditions, as well as counseling to prevent disease or promote health, childhood and adult immunizations, and postmenopausal estrogen replacement. Limiting its recommendations to those services for which clear experimental evidence of efficacy had been published, the task force was able to recommend routine screening for only six conditions, plus administration of childhood immunizations and counseling to prevent tobacco use.

Aspirin has been reported to reduce heart attacks in males strikingly, but the evidence is conflicting and no similar studies in females are available. The possibility of a positive effect of aspirin treatment makes it urgent to further investigate prophylactic effects in both sexes (Hennekens et al. 1988; Steering Committee of the Physicians' Health Study Research Group 1989).

Screening

Of the conditions for which the task force recommended screening, we estimate that only screening for hypertension and cervical cancer will lead to an increase in life expectancy for the entire population.

Screening for Hypertension. The task force recommends that blood pressure "be measured regularly in all persons aged 3 and above." The efficacy of treating moderate and severe hypertension is well established; the efficacy of screening for hypertension will, however, depend also on correct prescription of treatment and on the patient's compliance with

correctly prescribed therapy. Hypertension may occur in as many as 58 million Americans, of whom an estimated 10 million adults are moderate or severe hypertensives. We estimate that an increase in life expectancy of five to six months since 1950 can be attributed to the treatment of hypertension. It is unclear how much of this gain should be credited to population screening rather than to incidental case finding during examination and treatment of other medical conditions; we tentatively credit one and a half to two months, or about a third of the gain, to population screening (table 1), and we ascribe three and a half to four months to incidental case finding (table 2).

Screening for Cervical Cancer. The task force recommends Papanicolaou testing for cervical cancer every 1 to 3 years with the onset of sexual activity. For the estimated 1.4 percent of women destined to develop cancer of the uterine cervix, Papanicolaou testing every 3 years beginning at age 20, with appropriate curative treatment at the time of diagnosis, is estimated to increase their life expectancy by 10 to 15 years. For all women, beginning at age 20, it is estimated that screening for cervical cancer every 3 years increases life expectancy by 96 days (Eddy 1990). With 60 to 90 percent of women reported to have been screened within the past 3 years (Muller et al. 1990), we estimate that two-thirds of this potential has been achieved for an increase in women's life expectancy of two months; we credit half to screening (table 1) and half to treatment (table 2).

Subsequent to publication of the *Guide to Clinical Preventive Services*, the efficacy of screening for colorectal cancer has been reported in a randomized study of fecal occult-blood testing (Mandel et al. 1993). Annual testing of 50- to 80-year-old men and women was found to decrease the 13-year cumulative mortality from colorectal cancer by 33 percent. Reducing by a third the age-adjusted death rate attributed to colorectal cancer, 13.6 per 100,000 in 1989, would amount to an increase in life expectancy of about a month. Several other trials are in progress; until their results are available, we credit annual screening with the potential to increase life expectancy by two weeks, and we assign half of this increase to clinical preventive services and half to clinical curative services.

Immunizations

Infectious disease, the most common cause of death in childhood at the beginning of the century, has become a rare cause of death today. In

TABLE 1
Clinical Preventive Services: Estimated Numbers at Risk and Gains in Life Expectancy for Those Receiving Selected Successful Services, with Gain in Life Expectancy for the U.S. Population and Potential Gain Not Yet Achieved

Clinical preventive service	Relevant population	Individuals affected by condition in the absence of preventive service	Gain per individual receiving preventive service	Proportion of those at risk receiving preventive service	Gain in life expectancy distributed across U.S. population	
					Current	Potential
Screening for hypertension	All over age 3	58 million ^a (10 million moderate or severe)	3 months	50%	1.5-2 months	1.5-2 months
Screening for cancer of cervix	Adult women	13,000 ^b	96 days	60%-90%	2 weeks ^c	1 week ^c
Screening for colorectal cancer	All 50-80 years of age	155,000 ^b	2 weeks	Unknown	Unknown	1 week
Counseling to stop smoking	Smokers	Smokers (approximately one-third of population) ^a	3 months	Unknown	Unknown	1 month
Immunization for diphtheria	All children	40 deaths per 100,000 ^b	10 months	73%-85% pre-school; 97%-98% entering school	10 months	0
Immunization for poliomyelitis	All	2,500 deaths ^b	3 weeks	73%-85% pre-school; 97%-98% entering school	3 weeks	0
Immunization for tetanus	All	2,500 deaths [†]				

Immunization for smallpox	All	NA ^d	3-6 months ^c	Almost all before immunization; almost nobody today	3-6 months	0
Immunization for influenza	All over 65	10,000-40,000 deaths ^b	3 weeks	30%	1 week	3 weeks
Pneumococcal immunization	All over 65	400,000 cases ^b	6 weeks	14%	1 week	6 weeks
Hepatitis-B immunization	All	21,000 cases ^b	1.5-2 weeks	10%	1-2 days	1.5-2 weeks
Hormone replacement	Postmenopausal women	8,000 deaths ^b	3 months	50%	3 weeks ^c	3 weeks ^c
Aspirin prophylaxis for heart attack	Men over 40	Approximately 30% of men	Unknown	Unknown	Unknown	Unknown

^a Prevalence (all cases).

^b Incidence (new cases per annum).

^c Double for single sex.

^d Not applicable following worldwide eradication.

^e Limited to this century only.

Sources: HYPERTENSION — MacMahon et al. 1990; Collins et al. 1990; Subcommittee on Definition and Prevalence of the Joint National Committee on Detection, Evaluation and Treatment of High Blood Pressure 1985. CANCER OF CERVIX — Eddy 1990. COLORECTAL CANCER — Mandel et al. 1993. COUNSELING TO STOP SMOKING — Taylor et al. 1987. IMMUNIZATION — Amler and Dull 1987; Centers for Disease Control 1986; Gardner and Schaffner 1993. HORMONE REPLACEMENT — Daly et al. 1992; Weinstein and Tosteson 1990. ASPIRIN PROPHYLAXIS — Hennekens et al. 1988; Steering Committee of the Physicians' Health Study Research Group 1989.

1900 the annual death rates for diphtheria, measles, and pertussis were 40, 13, and 12 per 100,000, respectively, whereas by 1960 there were no deaths reported for diphtheria, and only 2 and 1 per 100,000 for measles and pertussis. Most of the fall in death rates from measles and pertussis occurred before the introduction of their respective vaccines or the availability of antibiotics (McKeown 1979), and we can only credit the introduction of diphtheria antitoxin and subsequent immunization for the observed fall in mortality, equivalent to an increase in life expectancy of approximately 10 months.

Death rates from poliomyelitis and tetanus before the introduction of immunization against each were less than for measles, diphtheria, and pertussis; the rate for poliomyelitis varied between 0.4 and 1.8 per 100,000 in the 1920s, 1930s, and 1940s; and that for tetanus, between 0.7 and 1.7 in the 1920s and 1930s. Their virtual elimination following the achievement of nearly universal immunization represents an increase in life expectancy of about three weeks for both combined.

What conclusions can we draw regarding the contribution of immunization practices to health today? Measles offers a case in point. Although death attributed to measles is rare in the United States, the recently reported marked upsurge in cases of measles in unvaccinated, preschool children in the inner city raises the possibility of the return of measles-related death, deafness, and mental retardation (Hersh et al. 1992), as we discuss elsewhere (Bunker, Frazier, and Mosteller 1994). A waning appreciation for the importance of, and declining confidence in, immunization gives added cause for concern. Koplan et al. (1979) have explored the potential effect that curtailment of pertussis vaccination might produce. Using decision analysis, he and his colleagues predicted that there would be a 71-fold increase in numbers of cases and an almost 4-fold increase in deaths were pertussis immunization to be discontinued.

Summary of Contributions of Clinical Preventive Services to Life Expectancy

Table 1 shows the contribution to the national life expectancy of the clinical preventive services, both those described above and others we have evaluated. The last two columns suggest that the current gain is a year and a half, when averaged over the whole population, with the po-

tential for an additional seven or eight months. We call attention to the substantial gain from diphtheria immunization.

The Role of Medical Care in Extending Life: Clinical Curative Services

Cancer is a major cause of death in the United States, and although there have been dramatic improvements in the mortality statistics for a small number of individual malignancies, current data provide no evidence that medical care has reduced mortality when all cancers are added together. Only for colorectal and cervical cancers were we able to conclude that medical care has resulted in an improvement large enough to yield an increase in population life expectancy.

Colorectal cancer had a fall in age-adjusted death rates from 19.0 per 100,000 resident population in 1950 to 13.6 in 1989, equivalent to an increase in life expectancy of one month. This is roughly the level of improvement that has been reported in randomized trials of radiotherapy and adjuvant chemotherapy, but there is considerable disagreement about the interpretation of the trials (Sleven and Gray 1991; Taylor and Northover 1990), and much of the improvement is thought to be due to changes in diet. We credit medical care with half of the improved survival, and assign two weeks of increased life expectancy for the population as a whole, with the potential for an additional two weeks, one of which was assigned to screening in the previous section and in table 1.

In contrast to cancer, there have been dramatic improvements in survival of patients suffering from heart disease. Goldman and Cook (1984) have reviewed evidence of the efficacy of medical interventions that might contribute to the fall in cardiac deaths, and they estimate that 40 percent of the reported decline in the years between 1968 and 1976 could be attributed to medical care, chiefly coronary care units, treatment of hypertension, and medical treatment of ischemic heart disease.

Goldman and Cook's analysis was based on the improvement observed over an eight-year period. Cardiac mortality had fallen in the previous years and has continued to fall subsequently. The National Center for Health Statistics reports a fall in annual age-adjusted death rates for diseases of the heart from 307.2 per 100,000 resident population in 1950 to 155.9 in 1989. If 40 percent of this fall were the result of medical intervention, it would represent an increase in population life expectancy

of nearly a year and a half (see the appendix for calculation of life expectancy in heart disease).

The age-adjusted death rate for cerebrovascular disease fell from 88.6 per 100,000 in 1950 to 28.0 in 1989, representing an increase in life expectancy for the whole population of about a year and a third. Marked increase in medical control of hypertension during this period, from less than 10 percent to approximately 50 percent (Dridz, Dannenberg, and Engle 1986), and a 42 percent reduction in stroke observed in randomized trials of antihypertensive drugs (MacMahon et al. 1990; Collins et al. 1990) could explain as much as 15 to 20 percent of the reduction in stroke mortality, with an increase in life expectancy of from two and a half to three months, about half of the net effect assigned to screening and treatment in tables 1 and 2.

Among the most spectacular recent advances in medicine has been the treatment of kidney failure or end-stage renal disease by hemodialysis and kidney transplant. Prior to the introduction of these treatments and the funding of their cost under Medicare, chronic renal failure was uniformly fatal. Today the life expectancy of a 40-year-old suffering end-stage renal disease is 8.8 years, that of a 59-year-old, 4.2 years (United States Renal Data System 1991), advances that have added an estimated two to three months to the life expectancy of the population.

The discovery and introduction of insulin in 1921 brought about an abrupt decrease in the death rate from diabetes among Massachusetts residents 19 years old and younger. Scaled up to the size of the U.S. population today, insulin saves approximately 5,000 lives annually in this age group alone (Hamblen and Joslin 1927). The life expectancy of a patient with newly diagnosed diabetes mellitus prior to the introduction of treatment with insulin was less than two years, with all but 5 percent dead by the end of 10 years (Krolewski, Warram, and Christlieb 1985); the life expectancy of diabetics today is estimated to be shortened by approximately 12 years (National Center for Health Statistics, Curtin and Armstrong 1988), with the juvenile diabetic surviving on average to 50–55 years and the adult onset diabetic, to 60–70 years. The gain in life expectancy at birth in excess of 50 years for the juvenile diabetic must be considered as primarily the result of the discovery and introduction of insulin, but the introduction of antibiotics, the management of hypertension, and other improvements in dealing with the complications of diabetes have also contributed. Of the approximately 5.5 million diabetics in the United States, 0.5 to 1 million are juvenile and insulin dependent, and we estimate that almost all are alive today because of the

advances in medical care of this century. It is considerably more difficult to estimate the gain in life expectancy for the larger numbers of non-insulin-dependent diabetics because there are no reliable baseline data on their prognosis prior to the introduction of relevant therapeutic measures. Our best estimate, given this caveat, is that diabetics gain, on average, 25 years of additional life from medical care, and that the population as a whole gains six months in life expectancy.

The importance of the introduction of streptomycin in 1948 to treat pulmonary tuberculosis, followed by other effective antitubercular drugs, has been minimized by McKeown and others who point out that the mortality rate from tuberculosis had already fallen by 90 percent at the time when effective treatment was introduced (McKeown 1979). Pulmonary tuberculosis was still a major cause of death, killing an estimated 40,000 each year in the United States. The introduction of effective treatment was followed by a greatly accelerated further decline, to the point where tuberculosis had, until recently, nearly disappeared as a cause of death. Assuming that the mortality attributed to tuberculosis would have continued to fall without treatment, McKeown calculated that 51 percent of the subsequent decline could be attributed to treatment. We accept his estimate, and assign an improvement in life expectancy of three months to medical care.

Maternal deaths during this century have fallen from 27 per 100,000 women in 1900 to 5.4 per 100,000 in 1940 and to 2 per 1 million in 1987. This represents an increase in life expectancy for women of about six months during the century and of five or six weeks since 1940. Improved social conditions may have been responsible for much of the decline in maternal mortality early in the century. The introduction of antibiotics, the ready availability of blood transfusions by the middle of the century, and an overall improvement in obstetric and anesthetic care must be considered largely responsible for the continuing decline in mortality up to the present. We assign one month of the gain for women in life expectancy since 1940 to improvement in medical care.

Summary of Estimated Increase in Life Expectancy for the Population from Clinical Preventive and Curative Services

Table 2 shows the gains estimated from some curative services, both those described above and others that we have evaluated. They add some three

TABLE 2
Clinical Curative Services: For Selected Diagnoses, Estimated Numbers at Risk and Gains in Life Expectancy for Those Receiving Successful Treatment, with Gain in Life Expectancy for the U.S. Population and Potential Gain Not Yet Achieved

Condition treated	Relevant population	Number at risk	Gain per individual receiving successful treatment (years)	Gain in life expectancy distributed across U.S. population	
				Current	Potential
Cancer of cervix	Adult women	13,000 ^b	21 ^d	2 weeks ^c	1 week ^c
Colorectal cancer	All	155,000 ^b	12 ^d	2 weeks	1 week
Peptic ulcer	All	250,000 ^b	10 ^c	2 weeks	Unknown
Ischemic heart disease ^f	All	6 million ^a	14 ^c	1.2 year	6-8 months
Hypertension	All	58 million ^a	10 ^c	3.5-4 months ^g	3.5-4 months ^g
Kidney failure	All	41,000 ^b	11 ^c	2-3 months	Unknown
Infant respiratory failure	Premature infants	75,000-100,000 ^b	20-30 ^d	3-4 months	Unknown
Appendicitis	All	273,000 ^b	50 ^d	4 months	0
Diabetes	All	6 million ^a	25	6 months	Unknown
Pregnancy	Women 15-44	4 million ^b	45	2 weeks ^c	0
Pneumonia and influenza	All	400,000-1 million ^b	9 ^c	3 months	0

Tuberculosis	All	27,000 cases ^b	15 ^c	3 months ^b	Uncertain ^b
Trauma	All	50-65 million ^b	24-38	1.5-2 months	3-4 months

^a Prevalence (all cases).
^b Incidence (new cases per annum).
^c Double for women.
^d For cancer of the cervix, colon cancer, infant respiratory distress syndrome, and appendicitis, we have made rough approximations based on mean age at death and life expectancy at that age.
^e "Gain in expectation of life at birth due to eliminating specified cause of death by race and sex, for those who would have died; United States, 1979-81" (National Center for Health Statistics, Curtin and Armstrong 1988, table E).
^f Includes coronary-artery surgery, coronary-care units, and medical management of heart disease.
^g Impact of treatment of hypertension on stroke and heart mortality.
^h Increased likelihood of poor compliance with treatment regimens and increased frequency of infection with drug-resistant strains of tuberculosis make these estimates speculative and subject to change.
Sources: CANCER OF THE CERVIX AND COLON - Gloeckler Ries, Hankey, and Edwards 1990; American Cancer Society 1991. COLORECTAL CANCER - Gloeckler Ries, Hankey, and Edwards 1990. PEPTIC ULCER - Adams and Benson 1991; Fineberg and Pearlman 1981. ISCHEMIC HEART DISEASE - National Heart, Lung, and Blood Institute 1985. HYPERTENSION - Subcommittee on Definition and Prevalence of the Joint National Committee on Detection, Evaluation and Treatment of High Blood Pressure 1985; Collins et al. 1990; MacMahon et al. 1990. KIDNEY FAILURE - United States Renal Data System 1991. INFANT RESPIRATORY DISTRESS SYNDROME - Office of Technology Assessment 1987; Buehler et al. 1987. APPENDICITIS - Graves 1990. DIABETES - Adams and Benson 1991. PREGNANCY - National Center for Health Statistics 1991. PNEUMONIA AND INFLUENZA - National Center for Health Statistics 1992, 227; Williams et al. 1988. TUBERCULOSIS - Amler and Dull 1987. TRAUMA - Collins 1990; National Center for Health Statistics 1992; Trunkey 1990.

and a half to four years to life expectancy. The year and a half gain in heart disease comes from a collection of technologies (such as treatments of ischemic heart disease and hypertension) rather than from a single treatment such as immunization against diphtheria (see table 1). Within the framework of medicine as now practiced, we estimate that an additional one to one and a half years might be added by extending the use of current services to more people. Table 2 indicates that the field of trauma is a promising subject for further investigation.

All told, then, tables 1 and 2 illustrate an estimated current gain in life expectancy of about five years and a potential for adding one and a half or two more years, all derived from therapies already known to be efficacious.

The curative services seem to be making the larger contribution to length of life. In looking for potential sources of errors, one might ask whether we have undervalued the number of years of life gained from immunization or other clinical preventive services, or whether we are overcounting the number saved in curative services. We do not consider costs in this article, but it would be instructive to compare the cost effectiveness of preventive and curative services.

The Role of Medical Care in Improving Health Status and Well-Being or Quality of Life

The quality of life of individuals is influenced by social, environmental, economic, and occupational factors, as well as by health status. Health status is in turn influenced by medical care. Among the components of quality of life, morbidity and disability provide a measurable connection between medical care and quality of life.

From data collected by the National Health Interview Survey, excluding those individuals in nursing homes, it is estimated that, in 1990, between 33 and 34 million people had some degree of activity limitation due to chronic conditions, of whom nearly 23 million suffered limitation in major activity (Adams and Benson 1991). Data from the Survey of Income and Program Participation, which included information on functional limitations, work limitations, and receipt of Social Security or veterans disability benefits, indicate that there are "about 46 million people with some type of work or functional limitation" (quoted in Pope and

Tarlov 1991, 75). Only limited data are available to indicate the magnitude of the individual causes of disability, and we have few quantitative data on the potential role of medical care in ameliorating the national burden of disability. Indeed, most data suggest that the numbers of disabled persons are increasing; only in 1993 has evidence been presented that the prevalence and incidence of chronic disability have begun to decline (Manton, Corder, and Stallard 1993).

The role of medical care in improving the quality of life consists primarily in relief of pain and suffering and of physical, social, and mental dysfunction. The pain and dysfunction suffered by individuals are usually specific, or even unique, to a particular medical condition. Hence, to estimate the contribution of medical care to the improvement in the quality of life of the population, we consider the effects of specific treatments for each particular illness or condition. In doing so, we are adopting the same approach used in our forgoing estimates of the effects on life expectancy of individual treatments for individual conditions.

The application of formal, quantitative, condition-specific quality-of-life measurement methods is in an early stage of development, but there is abundant qualitative evidence of the role of medical care in improving function and in relieving the suffering of patients afflicted with particular illnesses. The formal studies already performed address the poor quality of life experienced in chronic illness (e.g., depression, AIDS, arthritis); the impact of some therapies in improving quality of life (e.g., the relief of angina pectoris by coronary bypass surgery, the improvement of function and relief of pain by hip replacement) at the risk of reduced life expectancy.

Impaired functional status, mental health, and perceived bodily pain of patients suffering from nine common medical conditions were documented in the Medical Outcomes Study. Each condition reflected a unique profile among the several indices of quality of life measured (Stewart et al. 1989; Tarlov et al. 1989). Hypertension had the least overall impact; congestive heart failure, myocardial infarction, and gastrointestinal disorders had the greatest. Depression, in a separate analysis, was found to have an associated worsening of function comparable with, or worse than, that of the other eight (Wells et al. 1989).

Impaired functional status, mental health, and bodily pain are the major complaints for which individuals seek relief by medical care. The severe pain of acute illnesses such as appendicitis, myocardial infarct, renal colic, and serious injury is relieved when successful treatment is fol-

lowed by recovery. It is the pain and suffering of chronic illness with which the medical professions are increasingly concerned; and it is the success in their relief for which documentation is needed and is currently being developed. We present two examples of areas where medical care has profoundly improved the quality of life: unipolar depression and the chronic pain of osteoarthritis and migraine. We also present the correction of refractive errors in vision as an example of a relatively inexpensive and simple medical contribution to the quality of life whose value is often overlooked.

Unipolar Depression

Unipolar depression (to be distinguished from bipolar, or so-called manic, depression) is a condition with high prevalence, high morbidity, and high aggregate cost. It affects an estimated 10.5 million adults at any one time, and 8 to 12 percent of males and 20 to 26 percent of females sometime during their lives. Half of those who have an initial episode of major depressive disorder from which they have recovered will experience at least one recurrence. An episode of major depression typically lasts six months or more in the absence of therapy. Effective treatment with antidepressive drugs, psychotherapy, or electroconvulsive therapy is, in principle, readily available and is effective in 70 to 80 percent of patients, but more than half of all persons with major depressive disorder are not brought into treatment, and roughly half of those who receive treatment do not get it in effective amounts (Leaf et al. 1985; NIH Consensus Development Panel on Depression in Late Life 1992; Frazier 1993).

Osteoarthritis

Osteoarthritis, a chronic illness of growing prevalence in the elderly, occurs in an estimated 6 percent of the population, as detected by radiologic examination, and in 0.5 percent of the population is accompanied by severe pain and physical dysfunction (Lawrence et al. 1989). The development and widespread use of total joint replacement to relieve pain and restore function has been one of the great success stories of medical care today. In 1989 there were 86,000 total or partial hip replacements and 41,000 knee replacements performed on American men and women aged 65 and over, at rates of 2.8 and 1.3 per thousand, respectively, in

that age group. With a life expectancy of 17 years at age 65, 3 to 4 percent of individuals over 65 will undergo replacement of one or both hips, and 1.5 to 2 percent will undergo replacement of one or both knees. More than a million men and women have undergone total hip or knee replacement; relief of pain has been achieved in 85 to 90 percent, and functional improvement has been seen in 70 to 80 percent (Liang, Cullen, and Poss 1982).

We are aware of the use of a number of anti-inflammatory agents for the amelioration of joint pains caused by osteoarthritis. In addition, a number of meta-analyses have been done of the effects of various drugs on the symptoms of rheumatoid arthritis. The latter reports include one kind of symptomatology, counts of tender joints, as an outcome variable. Another outcome variable relates to function: grip strength. In general, however, there is a paucity of information about the quantitative effects of drug treatment on pain or function, such as the activities of daily living, for patients suffering from rheumatoid or osteoarthritis, or for the whole population. For these reasons, we have elected not to include the general problem of the management of arthritis in our discussion of quality of life.

Migraine

Migraine, a disorder that presents itself in many different forms besides headache, can be profoundly disabling and is poorly understood, yet can often yield to medical care. Sacks states that "headache is the commonest complaint that patients bring to physicians, and migraine is the commonest functional disorder by which patients are afflicted." (1985, 31). He estimates that "common migraine" headache occurs in between 5 and 20 percent of the population, and that 1 or 2 percent suffer the more debilitating classical migraine. A mail survey by Stewart et al. led to the projection of "18 million females and 5.6 million males currently suffering from severe migraine headaches. A total of 8.7 million females and 2.6 million males suffer from moderate to severe disabling headaches. Of these, 3.4 million females and 1.1 million males experience one or more attacks per month" (1992, 69). The effective use of a wide spectrum of medications, tailored to the response of individual patients, together with a variety of supportive therapies, has allowed the majority to engage in their personal and work activities largely free of pain.

Refractive Errors of Vision

Among the many benefits that medical innovations have conferred, few have made as substantial and broad a contribution as eyeglasses and contact lenses. The major refractive errors are easily diagnosed and relatively inexpensively ameliorated. The contributions of eyeglasses and contact lenses are often undocumented and unappreciated. They have become benefits largely taken for granted by those who use them, which is almost all of the population at one time or another during their lives. Without them, millions would not be able to read, drive a car, or participate in many occupations and recreations.

Summary of Contributions of Medical Care to Quality of Life

Table 3 gives some notion of the numbers of people in the United States associated with a substantial set of improvements in quality of life, both for the illnesses mentioned and for others we have reviewed. The strength of the table lies in the evidence that millions of people have experienced relief of pain and improvement of function from the use of therapeutic drugs, surgery, medical management, and medical devices. These cures and ameliorations represent much of what we buy with our medical budget. A person who has not experienced a handicap or limitation of activity that hampers someone else may underestimate its importance to the afflicted person. But the miseries of depression, shortness of breath, angina, creaky and painful joints, severe pain, disabling headaches, major indigestion, urinary difficulties, toothache and sore gums, fuzzy vision, faulty hearing, paralysis, and broken bones would add up to a national disaster without the relief we are able to document.

As the final column of table 3 indicates, we are uncertain about the extent of application of these aids. How much relief can be given and at what additional cost must be left for future inquiry. But we anticipate much room for improvement. The main point is that much effective care can be and is being given.

The data we present in table 3 are measures of functional status and well-being that are specific to each diagnosis or condition. They do not lend themselves easily to a summary measure that would allow us to construct an inventory on a single outcome variable similar to the inventory

of condition-specific improvements in life expectancy charted in tables 1 and 2. The methodology to approach this, however, is available in generic measures of quality of life for each component, such as functional status, mental health, and perceived bodily pain. Baseline measurements for a number of diagnoses and conditions have already been reported from the Medical Outcomes Study (Stewart et al. 1989; Tarlov et al. 1989). We look forward to future reports that include generic as well as condition-specific measures of improvement in the quality of life as affected by medical care.

Trade-Offs between Quality and Length of Life

Much of surgery is intended primarily or partly to improve the quality of life: orthopedic joint replacement is intended to relieve pain and improve function; intraocular lenses are implanted to improve vision; hysterectomy is performed to relieve severe dysmenorrhea; and cochlear implants are done to improve hearing. Whether successful or not, all surgery, together with the necessary anesthetic, entails some risk of death or complication. In many, perhaps most, cases the risk is small, the anticipated benefit is relatively large, and the trade-off is therefore usually a favorable one: a potentially large improvement in the quality of life in exchange for a small loss in life expectancy. Alternatively, the risks may be large, and the benefits may or may not be sufficient to justify the risks. To make this judgment, that is, to make a risk-benefit assessment, it is essential that benefits, as well as risks, be accurately known.

Discussion and Conclusions

We have several objectives in describing this study. First, we want to illustrate a method for quantifying the improvement in life expectancy resulting from the application of one or a package of interventions to a particular condition. The method is dependent upon the prior collection of accurate information on the efficacy of the interventions, a requirement that cannot yet be met in the case of some important conditions and treatments. We call attention here to several circumstances that affect the validity and precision of our estimates. For example, the prolongation of life resulting from the treatment of hypertension can be

TABLE 3
Quality-of-Life Benefits: Effects of Treatments for Selected Conditions Estimated Numbers at Risk,
and Gains in Quality of Life for Those Receiving Treatment

Condition/ symptoms	Number at risk	Lifetime risk	Treatment	Magnitude of relief in treated patients	Proportion treated
Unipolar depression	10.5 million ^a	8%–12% men 20%–26% women	Drugs, ECT, psychotherapy	70%–80%	<50%
Ischemic heart disease and angina	6 million ^a 150,000–200,000 ^b	10%–15% men 3%–5% women	Coronary artery re- vascularization; drugs	50%–66% for 5 years	Unknown
Osteoarthritis pain, joint dysfunction	Joint replacements: 86,000 hip ^b 41,000 knee ^b	3%–4% hip 1.5%–2% knee	Joint replacement	85%–90% pain relief; 70%–80% functional improvement	Unknown
Terminal cancer (severe pain)	450,000–475,000 ^a	30%	Analgesic drugs	Nearly complete relief	40%–50%
Peptic ulcer (severe pain)	250,000 ^b	10%–15% men 4%–15% women	H ₂ -receptor- blocking drugs	80%–90% healed in 4–8 weeks	Unknown
Gallstones with biliary colic	0.5–1 million ^b	9% men 27% women	Cholecystectomy	67% pain relief at 2 years	Unknown
Migraine, severe	5.6 million men ^a 18 million women	10%–15%	Medication	50%–75% relief	Unknown

Postoperative pain	22 million operations ^b	90%	Epidural anesthesia; self-medication	Nearly complete relief	<25%
Benign prostatic hypertrophy	125,000 ^b	20%–45%	Prostatic resection, drugs, etc.	79%–93% relief of symptoms	Unknown
Osteoporosis and fracture	1 million ^b (women)	10%–12% by age 65; over 20% at 80	Hormone-replacement therapy; calcium	20% reduction in fractures in 1st 2 years, then 60% reduction	50%
Poliomyelitis with paralysis	All	0.5%–1% prior to 1950	Vaccine	Nearly complete protection	74% preschool; 98% entering school
Nonfatal stroke	1.9 million ^a	5% by age 70	Treatment of hypertension	50% reduction in incidence	50%
Asthma	10 million ^a	5%–10%	Medication	Relief of dyspnea, cough, and wheezing	50%
Myopia and presbyopia	All but the blind	Nearly 100%	Lenses	Visual acuity adequate for most activities	Nearly all at some time
Cataract	6 million ^a	5%–10%	Lens removal; intraocular implant	75%–95% improvement in visual acuity	Unknown
Impaired hearing	18 million ^a elderly	35%–50%	Hearing aid	Improved social function, communication	Unknown
Trauma	50–65 million ^b	Nearly all	Surgical correction, rehabilitation	Restoration of function, pain relief, improved appearance	Unknown

continued

TABLE 3 continued

Dental health condition	Lifetime risk	Treatment	Relief of symptoms	Proportion treated
Cavities	80%	Fillings	Pain relief, restoration of function	70%
Periodontal disease	20%	Surgery and/or antibiotics	Pain relief, Retention of teeth	50%
Edentulism	8% (75% are 65 and over)	Dentures and/or implants	Restoration of appearance, speech, ability to eat	Unknown
Malocclusion	54%	Orthodontics	Restoration of appearance, speech, ability to eat	20% if uninsured, 70% if insured

^a Prevalence (all cases).

^b Incidence (new cases per annum).

Sources: DEPRESSION — Boyd and Weissman 1981; Frazier 1993. ISCHEMIC HEART DISEASE AND ANGINA — We are not aware of data on the nationwide incidence or prevalence of angina. As an approximation, we assume an incidence of between one-half and three-quarters the number of coronary-bypass operations, for which angina is a major indication. Over 200,000 bypass operations are performed annually (Feinleib et al. 1989; see also Califf et al. 1989; Winslow et al. 1988; and Alderman et al. 1982). OSTEOARTHRITIS — Lawrence et al. 1989. CANCER, TERMINALLY ILL—Bonica 1986. PEPTIC ULCER — Adams and Benson 1991; Fineberg and Pearlman 1981. GALLSTONES WITH BILIARY COLIC — Incidence estimated indirectly from prevalence of gallstones and variations in incidence of biliary-tract-related pain reported in patients with previously demonstrated gallstones (Thistle et al. 1984; Ransohoff et al. 1983; Bates et al. 1991). MIGRAINE — Stewart et al. 1992. ADAMS AND BENSON 1991. POSTOPERATIVE PAIN — Acute Pain Management Guideline Panel 1992. BENIGN PROSTATIC HYPERTROPHY — Over 350,000 prostatectomies are performed annually in the United States. In a nonrandomized group of 318 patients scheduled for prostatic resection, 38% were classified as severely symptomatic (Fowler et al. 1988). We estimate that approximately 125,000 of prostatectomies are performed for severe symptoms. The risk of undergoing prostatectomy by age 80 has been reported to vary between 20% and 45% (Wennberg and Gittelsohn 1982). OSTIOPOROSIS AND FRACTURE — Weinstein and Tosteson 1990; Daly et al. 1992. POLIOMYELITIS — Centers for Disease Control 1986. NONFATAL STROKE — There are an estimated 1.9 million stroke patients in the United States, with a probability of suffering a stroke by age 70 of 5% (Kannel, Thom, and Hlurs 1986). About two-thirds are nonfatal (Collins et al. 1990). ASTHMA — Amler and Dull 1987; see also Anderson et al. 1981, 1983. MYOPIA AND PRESBYOPIA — Curtin 1970. CATARACT — Adams and Benson 1991; Office of Technology Assessment 1988; Brenner et al. 1993. HEARING — Mulrow et al. 1990. TRAUMA — Collins 1990; Trunkley 1990; National Center for Health Statistics 1992. DENTAL HEALTH — Burt and Eklund 1992.

initiated by active screening programs to discover hypertensives, on the one hand, or by incidental discovery of hypertension in the course of managing unrelated complaints, on the other. The assignment of medical benefit to either method of case finding is somewhat arbitrary, although the overall incidence of hypertension, however discovered, has a more secure empirical basis.

Another source of approximation in the assignment of benefits stems from the interactions among different conditions and treatments. For example, the discovery and treatment of hypertension is reflected in a decline in cerebrovascular and kidney diseases. More frequent discovery and management of hypertension also reduce the burden of heart disease, but estimates of just how much are confounded by concurrent improvements due to better diet and more exercise.

We also note that we have not included in our estimates of the benefits of preventive services those due to lifestyle changes that depend on individual initiative rather than on interventions by credentialed caregivers. We omit these important lifestyle changes in order to avoid giving medical care credit for improvements that can be availed of outside the system for professional medical care. We have chosen to restrict our application to conditions of high prevalence that carry a risk of fatal outcome, and that have a treatment of proven efficacy for a component of the U.S. population.

Our second objective is to discover what the results of the method can tell us about the problems in, or opportunities for, the deployment of resources to improve health. What do the results tell us about successful programs, unmet needs, and unrealized potential? Several points deserve emphasis.

We stress once again the critical importance of the results of systematic, ongoing assessment of medical technology, where technology is used in the broadest sense. Knowledge of efficacy, effectiveness, cost, and impact are not the sole determinants of policy decisions, but they powerfully inform our choices.

Our results in tables 1 and 2 show some unanticipated effects. The current effects of preventive measures on life expectancy (roughly 18–19 months) are less than half as great as the prolongation of life from curative measures (roughly 44–45 months). We do not argue for de-emphasis of preventive interventions simply because their impact is less; rather, we urge that curative interventions not be ignored in competition with prevention for available resources. Studies of the cost-effectiveness of a port-

folio of preventive, compared with curative, services would be especially useful here.

We note the unrealized potential for preventive services in the cases of hypertension (estimated at 1.5–2 months from programmatic screening), counseling regarding smoking cessation (1 month, but possibly much more), and immunization against pneumococcal pneumonia (1.5 months).

The unrealized potential of curative interventions includes packages of services for heart disease as noted above (6–8 months), treatment of hypertension in reducing stroke (1–1.5 months), and treatment for trauma (3–4 months).

Our third objective is to support the growing recognition that health care recipients value health status and well-being, or quality of life, regarding it as having an importance at least equal to life expectancy. Our analysis both of life expectancy and of quality of life is anchored in an approach through individual conditions, the effects of which are then aggregated. In the case of life expectancy, the aggregation may confront problems of data quality, but because the aggregation occurs on a single outcome variable, many problems are simplified.

Assessing quality of life is substantially more complicated. Two decades of work by others have done much to define and organize a set of basic components of global quality of life in the realm of social functioning, physical mobility, capacity for self-care, mental health, and pain. These generic measures permit some comparisons of quality of life across condition–intervention pairs, or the gain in generic measures with time after intervention. Where more specificity is required, condition-specific measures may be added in what amounts to a trade-off between aggregation and generality, on the one hand, and sensitivity and relevance, on the other. Our belief is that recourse to either generic or condition-specific measures should be determined by the purpose of the description, and that both types of measures have an important place.

In table 3, for example, comparisons across conditions require a method for weighting the impact on quality of life of repeated, short episodes of disability, as in asthma, or with chronic, unremitting pain, as in metastatic cancer. That decided, the investigator may design a data-acquisition system to capture the time/intensity measure and the qualitative generic measure. In the case of chronic conditions, the choice of a generic measure would be influenced by the condition–intervention pair under study and the purpose of the study. For example, the generic

measure of performance in social role could be used across the conditions of unipolar depression and terminal cancer in studying treatment with mood-elevating drugs. Table 3 identifies large groups in need of treatment who are receiving it, but also indicates that many are not.

Our fourth objective is to point out that the need for information on the outcome variables of efficacy and effectiveness, and measures of altered quality of life, can only increase as resources become more constrained, technology proliferates, and health care emphasizes functional status and well-being over simple survival. Organizing the relevant information for the use of physicians and their patients could be achieved by developing and routinely updating an inventory of condition-intervention pairs such as we have illustrated here. Such data might most appropriately be incorporated into the routinely published reports of the U.S. Public Health Service. An inventory of this type is urgently needed to assist social institutions (such as the Oregon Medicaid project) in making the value judgments involved in setting priorities and allocating resources.

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Appendix: Estimating Gains in Life Expectancy

In estimating the gains in life expectancy for a specific disease and preventive or curative service, we used several approaches. In some instances, we could base our estimates on governmental investigations of the anticipated effect of eliminating a disease altogether. This approach pays attention to the process of the disease as it attacks a cohort year by year. For several conditions (heart disease, cerebrovascular disease, pneumonia), we extrapolated from National Center for Health Statistics (NCHS) estimates of gains in "expectation of life due to elimination of specified causes of death" (National Center for Health Statistics, Curtin and Armstrong 1988). More precise estimates could be made for heart

disease and cerebrovascular disease by adjusting the 1988 life table for the age-specific 40-year decline in mortality published in *Health, United States 1991* (National Center for Health Statistics 1992).

Adjusting the Standard Life Table for Heart Disease

For heart disease and cerebrovascular disease, *Health, United States, 1991* provides age-specific death rates per 100,000 resident population by 10-year intervals for selected years beginning with 1950 (National Center for Health Statistics 1992). Table 33 (pages 163–4) provides these for “diseases of the heart, according to sex, race, and age.” The abridged life table for 1988 (U.S. Department of Health and Human Services 1991) gives the number of deaths from all causes of a cohort “of 100,000 born alive” by 5-year age intervals and the number remaining alive at the beginning of each age interval. To the deaths for each 5-year interval we added the additional deaths from diseases of the heart that would have occurred in 1989 had the death rate from heart disease remained unchanged from that of 1950. These additional deaths were calculated on the basis of the 39-year fall in death rate for each 10-year age interval, adjusted for the fall in numbers of survivors at the beginning of the interval. The adjusted numbers of individuals living at the beginning of each 5-year interval were then converted to the “stationary population” on which the life expectancy estimate is based.

Using this procedure, we calculated that the fall in death rate for diseases of the heart that occurred between 1950 and 1989 was responsible for an increase in life expectancy of approximately 3.49 years, 40 percent of which is distributed between treatment of ischemic heart disease and screening and treatment of hypertension shown in tables 1 and 2.

Estimating Life Expectancy from Age-Adjusted Death Rates

For most diagnoses, death rates from 1950 to 1989 are given by a single, age-adjusted number. To test the reliability of limiting the basis on which to estimate changes in life expectancy to age-adjusted, rather than age-specific, death rates, we compared this approach with the results of the life-table-based calculation. The age-adjusted death rate for all causes fell from 840.5 per 100,000 in 1950 to 523.0 in 1989, a drop of 317.5; that for diseases of the heart fell from 307.2 to 155.9, a drop of

151.3. Life expectancy for the same years rose 7.1 years. The fall in age-adjusted death rate for diseases of the heart contributed just under half of the fall in the death rate for all causes ($151.3/317.5 = .48$), which, multiplied by 7.1, yields 3.38 years as an approximation of the increase in life expectancy attributable to diseases of the heart.

Estimating from U.S. Life Tables *"Eliminating Certain Causes of Death"*

A second approximation of gain in life expectancy from the fall in death rates attributable to heart disease was made by extrapolating the National Center for Health Statistics projections for the gain in life expectancy that would occur by "eliminating specified causes of death" (National Center for Health Statistics, Curtin and Armstrong 1988). Elimination of all "diseases of the heart" from the 1979-81 life table was estimated to increase life expectancy by 5.79 years. The age-adjusted mortality from diseases of the heart was 202.0 per 100,000 resident population at that time; it fell to 155.9 in 1989, a fall of just under 25 percent. If eliminating all deaths from heart disease at a time when the death rate was 202.0 would increase life expectancy by 5.79 years, then a fall of 151.3 (307.2 in 1950 to 155.9 in 1989) should increase life expectancy by $3/4 \times 5.79 = 4.34$ years (or, more precisely, $155.9/202.0 \times 5.79 = 4.47$). Thus, the approximations are seen to change estimates in life expectancy by 10 or 20 percent.

For projections of increase in life expectancy accompanying the fall in the rate of death caused by cerebrovascular disease, we were able to construct a life table from age-specific death rates similar to that described above for heart disease, and also to use both of the approximations; for pneumonia and influenza, both approximations; for colorectal disease, the approximation based on the fall in age-adjusted death rate; and for duodenal ulcer, extrapolation from the 1979-81 life tables eliminating specified causes of death.

For a few conditions we had no such basis available. For two of these conditions (screening for cervical cancer, hormone replacement therapy) we accepted estimates of improvements in life expectancy as presented in the relevant publication. Sources of available data are listed together with the tables.

The reader should recognize that in our estimates of improvements in life expectancy we have accepted different baselines for different condi-

tions and treatments, with the choice of baseline depending on when an effective treatment became available or, in several cases, when reliable data became available. Thus, the improvement in life expectancy attributable to smallpox vaccination could be traced to the middle of the 19th century; to appendectomy, to the beginning of the present century; to the treatment of diabetes, to the introduction of insulin in 1921; and for the sharp decline in maternal mortality, to the introduction of antibiotics and availability of blood transfusions. Estimates for increases in life expectancy for patients with heart disease, hypertension and pneumonia, on the other hand, were made on the basis of the availability of mortality data from 1950 to the present, and earlier gains that may have been achieved were therefore missed.

Some of the conditions for which we have estimated increases in life expectancy are not independent of each other: for example, the treatment of hypertension may achieve some of the gain we attribute to the medical treatment of ischemic heart disease and diabetes. Weaker interactions may occur between less obviously related conditions: the patient who is spared from death of heart disease may be at increased risk of death from other causes. These "competing risks" are a problem that a deeper analysis based on better data might try to address.