THE COSTS AND BENEFITS OF INTENSIVE TREATMENT FOR CARDIOVASCULAR DISEASE

David Cutler
Mark McClellan
Joseph Newhouse

Working Paper **6514**

NBER WORKING PAPER SERIES

THE COSTS AND BENEFITS OF INTENSIVE TREATMENT FOR CARDIOVASCULAR DISEASE

David Cutler
Mark McClellan
Joseph Newhouse

Working Paper 6514
http://www.nber.org/papers/w6514

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 1998

We are grateful to Ernie Berndt and Zvi Griliches for helpful comments, and to the Bureau of Labor Statistics, Eli Lilly, and for financial support from the Bureau of Economic Analysis and the National Institute on Aging through grants to the National Bureau of Economic Research and Stanford University. Any opinions expressed are those of the authors and not those of the National Bureau of Economic Research.

The Costs and Benefits of Intensive Treatment
for Cardiovascular Disease
David Cutler, Mark McClellan
and Joseph Newhouse
NBER Working Paper No. 6514
April 1998

ABSTRACT

This paper examines the causes and consequences of reductions in cardiovascular disease mortality, and in particular heart attack mortality, over the past several decades. Analysis of data from Medicare and review of the clinical literature indicate that a large share of the recent decline in heart attack mortality is a result of new medical interventions and increased use of existing interventions. Much of the mortality improvement appears to be the result of changes in the use of pharmaceuticals such as aspirin and clot-busting (thrombolytic) drugs. Greater use of these and other intensive medical procedures have increased the cost of treating heart attacks but have also lead to health improvements. We estimate that the value of improved health is greater than the increased cost of heart attack care, so that the cost of living for people with a heart attack is falling. We present preliminary evidence that patients in managed care receive nearly similar treatment for heart attacks compared to patients with traditional indemnity insurance, but that managed care insurers pay less for the same treatments than do traditional insurers.

David Cutler
Department of Economics
Harvard University
Cambridge, MA 02138
and NBER
dcutler@fas.harvard.edu

Mark McClellan
Department of Economics
Stanford University
Stanford, CA 94305
and NBER
markmc@texas.stanford.edu

Joseph Newhouse
Division of Health Policy
Research and Education
Harvard Medical School
180 Longwood Avenue
Boston, MA 02115
newhouse@hcp.med.harvard.edu

Cardiovascular disease is among the most important health problems in the United States. Table 1 shows the leading causes of death in the United States in 1994. Heading the list is cardiovascular disease -- diseases of the heart and cerebrovascular disease. The annual mortality rate from cardiovascular disease is a little over .3 percent. Second in importance -- but only 60 percent as large -- is cancer. Chronic obstructive pulmonary disease is a distant third. The high mortality from cardiovascular disease is indicative of its enormous economic burden. Recent estimates have put the burden of cardiovascular disease in the United States at $110 billion annually, and cardiovascular disease is projected to become the leading cause of death in the world over the next several decades. Indeed, the prominence of cardiovascular disease in mortality has been true for some time: it has been the leading cause of death in the United States since the turn of the century.

What is striking about mortality from cardiovascular disease, however, is not just its magnitude but how rapidly it has declined over time. Figure 1 shows age-adjusted cardiovascular disease mortality from 1950 to 1994. Cardiovascular disease mortality fell by 60 percent between 1950 and 1990.[1] The decline is pronounced, and continues to this day.

In addition to falling mortality, the health of cardiovascular disease survivors is also improving. Table 2 shows changes in functional status for people diagnosed with ischemic heart disease.[2] Over the past two decades, the share of people whose usual activity was limited by ischemic heart disease fell rapidly, and the share with no limitations rose. The percent of people reporting overall poor health also fell.

In this paper, we focus on this dramatic improvement in cardiovascular health, and its

---

[1] The values in Figure 1 are adjusted to the age distribution of the population in 1950, and thus do not match the data in Table 1, which uses the 1990 population.

[2] These numbers are taken from various Health Interview Surveys. See Cutler and Richardson (1997) for more discussion as well as age adjustments.

implications for understanding the medical sector. Knowing just that cardiovascular health has improved is not enough; understanding the importance of this trend requires asking several other questions as well: why has cardiovascular health improved? has the money spend on cardiovascular disease care been "worth it"? how are changes in the medical sector affecting this benefit-cost calculation? In this paper, we address these questions.

We analyze in particular the costs and benefits of care for heart attacks -- a major and particularly severe form of cardiovascular disease. We direct our attention to heart attacks for several reasons. First, heart attacks are a common form of cardiovascular disease, and among its most serious consequences; thus, mortality will be a good measure of outcomes. Heart attacks are also expensive. Medicare spends over $14,000 per patient on hospital bills alone in the year after a heart attack, plus additional amounts for physicians and outpatient care. Further, these costs have been increasing at a rate of 4 percent per year in real (relative to the GDP deflator), per capita terms. By analyzing the value of heart attack treatment, we can learn a great deal about the costs and benefits of medical care in a situation where spending is rising rapidly. Finally, data to analyze heart attack treatments are easier to obtain than are data for other cardiovascular conditions, or other medical conditions more generally.

Our analysis addresses four specific questions. The questions, and the answers that we give, are:

1. What factors have led to reduced mortality for heart attack sufferers over time?

   To address this question, we have undertaken a comprehensive literature review of publications in the last 15 years addressing trends in AMI patient characteristics, *treatments, outcomes, and costs of care between 1975 and 1995. We find that changes in acute treatments such as use of aspirin, beta blockers, thrombolytic drugs, and (to a limited extent) invasive procedures account for a substantial part of the improvement in mortality. Trends in "secondary prevention" have also probably contributed to improved health, although population data on trends in secondary prevention are sketchy and discerning these effects from long-term consequences of changes in acute treatment is difficult. Changes in individual risk factors related to behavior rather than medical technology have played only a limited role. These findings are confirmed by our analysis of medical claims and outcomes measures for Medicare beneficiaries suffering a heart attack.*

2. What accounts for the rapid increase in the cost of heart attack care over time?

   Using data on everyone in the Medicare population with a heart attack between 1984 and 1991, as well as heart attack records from a Major Teaching Hospital between 1983 and 1995, we find that increasing costs of heart attack care are due almost entirely to increasing intensity of medical treatments. Reimbursement for a given type of therapy has been essentially unchanged.

3. How do the costs of increasing technology in heart attack care compare to the benefits of that care?

   We estimate that between 1984 and 1991, life expectancy after a heart attack rose by 8 months. Assuming rather conservative values for the benefit of additional lifeyears, the dollar value of this additional life is greater than the increased costs of medical care. The *implication of this finding is that a cost of living index for heart attack episodes fell, most likely by 1 percent or more annually.*

4. How will changes in the medical care environment, particularly the growth of managed care, affect the nature of heart attack treatment?

   When we compare heart attack patients treated in managed care and fee-for-service settings, we find that managed care plans in Massachusetts spend substantially less on heart attack care than fee-for-service plans. The cost difference is almost entirely a result of differences in the prices paid for equivalent care, rather than differences in the quantity of care received.

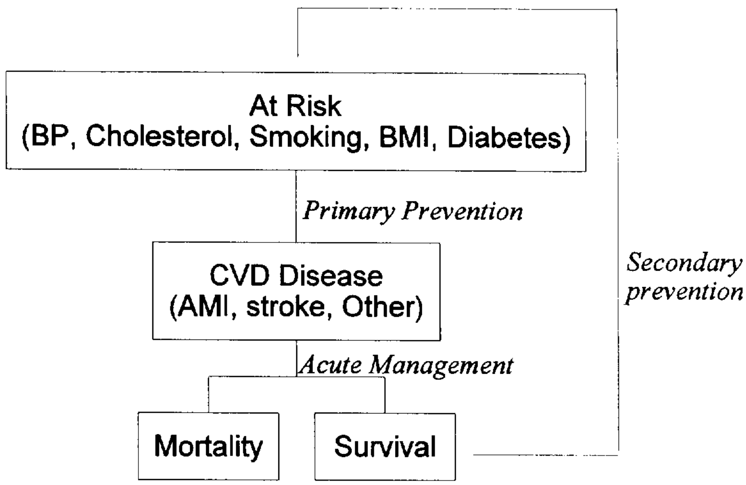
In the remainder of this paper, we discuss these questions and our answers to them.

I. The Nature of Cardiovascular Disease

We begin with a description of cardiovascular disease, to set the stage for our subsequent analysis. The path of cardiovascular disease is depicted in Figure 2. People initially engage in actions or have other diseases that place them at risk of a major cardiovascular illness. The most important risk factors are high blood pressure, high levels of cholesterol, smoking, obesity, and diabetes (Hunink et al., 1997; Braunwald, 1997).

Some people with elevated risk for cardiovascular illness (and some whose risk is not elevated) will suffer a serious cardiovascular event. These events include acute myocardial infarction (AMI, or heart attack), atherosclerosis, and cerebrovascular disease (stroke). Longer-term consequences of these illnesses include congestive heart failure (chronic weakening of the heart muscle). The process of preventing individuals with or without known risk factors from developing serious illness is termed *primary prevention.*

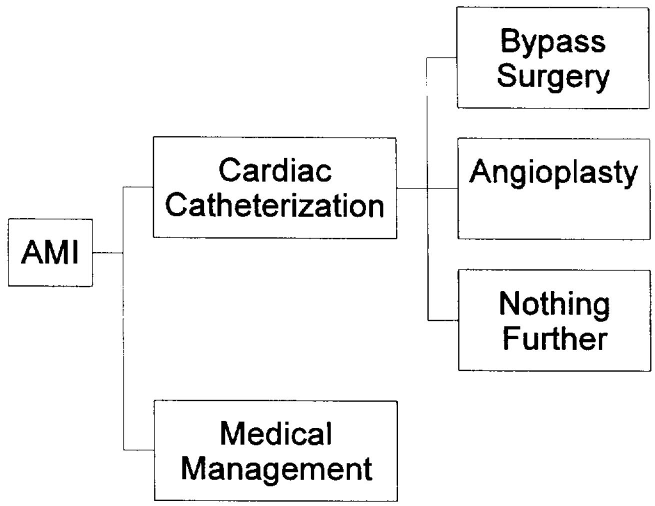
Figure 2: Cardiovascular Disease Progression



For an individual who suffers a major cardiovascular illness, there is a period of *acute disease management.* This period generally lasts about 90 days, although many critical treatments are delivered in the first few hours after the heart attack begins, and some therapies may be provided for up to several years after the event. Figure 3 shows the potential acute phase treatments for patients with a heart attack. One treatment method involves *medical management* of the heart attack. In the acute period medical management includes cardio-pulmonary resuscitation, drug therapies such as aspirin administration to prevent clot expansion and thrombolysis to dissolve the clot, monitoring technologies, and other nonsurgical intensive interventions for complications such as heart failure or irregular heart rhythms. Later, it may include drug therapy and counseling to promote a healthy lifestyle and reduce the risk of future heart attacks.

Invasive treatments[3] for heart disease begin with *cardiac catheterization* -- a diagnostic radiologic study of blood flow to the heart muscle. If a catheterization detects significant blockage, a range of revascularization procedures may be applied. Two major types of revascularization procedures have become widely used: *bypass surgery*, a major open-heart operation that involves bypassing blocked blood vessels by splicing a vein or artery around the blockage, and *angioplasty*, a percutaneous (less invasive) procedure that seeks to restore blood flow via inflating a balloon amid the blockage.

Figure 3: Treatment of Patients with a Heart Attack



If the individual survives the acute phase, there is then a period of *secondary prevention and complication management*, designed to prevent the recurrence of an acute episode as well as to minimize any functional consequences of heart damage from the attack. The factors involved in secondary prevention are the same as those in primary prevention – managing blood pressure and

[3]We define "invasive" treatments as catheterization and revascularization procedures. Many other "medical" treatments of AMI are also invasive, strictly speaking, but considerably less so than the major cardiac procedures that follow.

cholesterol, encouraging weight reduction, and exercise. Secondary prevention is particularly important, however, because individuals who have had a heart attack are at considerably higher risk of additional damage from the progression of heart disease. In addition, if the heart is weakened after the initial attack, medical treatments to support heart failure may be beneficial.

Sources of Health Improvement

Improvements in cardiovascular mortality and morbidity have resulted from a combination of primary prevention, acute disease management, and secondary prevention and complication management. All of these factors involve both medical and non-medical components. The important question is how to parcel out these different effects, and in particular to gauge the importance of medical and non-medical interventions in improved cardiovascular health.

The introduction of many primary and secondary therapies is at least coincident with the reduction in cardiovascular disease mortality. Table 3 shows key dates in the introduction of many pharmaceuticals used in cardiovascular care. Though cardioprotective effects of several drugs have been known for some time,[4] most of the major drug treatments used for ischemic heart disease were developed since the 1950s. The first oral diuretics (for blood pressure reduction) were introduced in 1959. beta blockers (to reduce the workload of the heart) were first developed in 1962, calcium-channel blockers (which also reduce heart workload through effects on cardiac contractions) were initially developed in 1971, and ACE inhibitors (which reduce the "afterload" facing the heart) were initially developed in 1979. Over the years, many modified versions of all of these compounds have

4 Nitroglycerin was first used to treat angina pectoris in 1879, and digitalis use for heart failure also dates back to the nineteenth century.

been developed, with intended goals of improving effectiveness and reducing side effects of the treatments.

Innovation in acute care management has also been rapid. Table 4 shows the major technologies used in the treatment of major cardiovascular events (including AMI and heart failure) and when they were introduced. Cardiac catheterization was first performed in 1959, and open-heart coronary artery bypass graft surgery was initially developed in 1968. The 1970s saw the advent of cardiac ICUs, and thrombolytic drugs (first developed in the 1970s) began to be more widely applied in the 1980s. In the 1980s and 1990s, there has been a diffusion of angioplasty, which was first developed in 1978. In addition to these technologies, there are many other "technologies" relevant to acute treatment: the provision of basic and advanced cardiac life support; the expertise of EMTs, paramedics, and other emergency response personnel; the specialization of nursing care for cardiac cases; etc.

There is substantial debate about the importance of different factors in explaining reductions in cardiovascular disease mortality. Most likely, all of them have been important, and their importance is likely to have varied over time. Examinations of mortality reductions between 1950 and 1970 typically place a large role on primary and secondary prevention (Goldman et al. 1984). This was the time period of the Surgeon General's first report on the dangers of smoking (1965), so primary and secondary prevention would naturally have a large role to play in this time period. Studies of more recent years have attributed a larger role to medical interventions. Between 1980 and 1990, for example, Hunink et al. (1997) estimate that 43 percent of mortality reductions resulted from acute disease management.

But debate on this issue is not settled. Aggregate trends in cardiovascular disease health are difficult to interpret. Further, it is particularly difficult to answer the subsequent questions that we want to ask, such as the cost-benefit analysis of medical interventions. To consider these factors, we focus on one type of cardiovascular illness in detail – the treatment of heart attacks.

II. The Efficacy of Heart Attack Treatment[5]

To examine the sources of mortality improvement in detail, we focus on the treatment of patients with one particular form of cardiovascular disease -- a heart attack. We focus on heart attacks for several reasons: (1) they are perhaps the most severe manifestation of cardiovascular disease, so that mortality after a heart attack is quite important; (2) they are expensive, leading to questions about what we are getting for our money; (3) they are common; and (4) people with a heart attack will necessarily be admitted to a hospital, so that data on heart attack treatments and costs are easier to obtain than data on treatments and costs for many other condition.

Heart attack mortality has fallen substantially over time. In 1975, according to death records maintained by the National Center for Health Statistics, heart attacks caused approximately 315,000 deaths. By 1995, that figure was down to 215,000, a reduction of almost one-third (National Center for Health Statistics, 1997). According to the National Hospital Discharge Survey, approximately 454,000 hospitalizations for heart attacks occurred in 1975, increasing to approximately 590,000 heart attacks in 1995.[6] But the in-hospital mortality rate declined from 22 percent to 12.5 percent.

---

[5]The analysis of this section draws heavily on Heidenreich and McClellan (1997).

[6]This increase resulted primarily from demographic changes associated with population growth and aging: according to NCHS, the incidence rate of heart attacks increased only slightly (0.21 percent to 0.22 percent).

This decline in deaths also corresponds to a mortality decline of approximately 30 percent.[7] We are interested in explaining what factors account for such rapid reductions in heart attack mortality, in the presence of rather modest changes in heart attack incidence.

To measure changes in the treatment of heart attacks over time, we compiled results from the universe of clinical studies published in the medical literature. The field is enormous; there are literally hundreds of published studies and meta-analyses of heart attack treatments and their effectiveness which we reviewed. We divide our review into changes in heart attack patient characteristics, changes in the acute treatment of heart attacks, and changes in other components of medical therapy (including pre-hospital care and secondary prevention). Because far more complete data are available on acute management than on other components of heart attack care, we analyze the consequences of these treatment changes in detail.

Changes in heart attack patient characteristics. Several population studies suggest little change between 1975 and 1995 in the characteristics of heart attack patients that might lead to mortality differences. The average age of AMI patients in the Minnesota and Worcester registries, and the proportions of male and female patients, were essentially constant. Slightly more patients have been diagnosed with shock at the time of AMI presentation (7.5 percent in 1975 versus 9 percent in 1988 in the Worcester population), suggesting increased mortality risk. On the other hand, the proportion of anterior MIs, which are also associated with higher mortality, appears to have

[7]Note that the number of in-hospital AMI deaths (around 100,000 in 1975, and around 70,000 in 1995) is substantially smaller than the total number of AMI deaths. The discrepancy is due to deaths occurring before hospitalization, and deaths after discharge. But both sources of information on AMI mortality give a similar picture of substantial improvement.

declined. In addition, the proportion of non-Q-wave infarcts (which are associated with lower acute mortality) has increased, though this may well be a consequence of more effective acute restoration of blood flow. Finally, significantly fewer patients have high blood pressure at the time of their AMI, which may also be associated with lower mortality. Together, these factors suggest that average AMI case severity decreased slightly, potentially accounting for 10 percent to 20 percent of the decline in the average AMI mortality rate. Note that we do not attempt to distinguish the role of behavioral factors versus medical therapies like antihypertensive medications in accounting for these modest improvements. Their collective effects appear to be quite modest.

Changes in acute treatments. Table 5 shows summary results of the share of heart attack patients receiving a range of acute treatments (that is, treatments during or soon after the initial heart attack hospitalization), from the mid-1970s to the mid-1990s. The upper panel of the Table shows data on pharmaceutical treatments, which have changed substantially over this time period. Thrombolytics, for example, were not used in heart attack care in1980, but were used in almost one-third of heart attacks by 1995. The use of aspirin, beta blockers, and heparin also increased. Calcium-channel blocker use increased rapidly in the early 1980s and then fell, following the publication of studies documenting potentially harmful effects of their use in acute management. Use of lidocaine and other antiarrhythmic agents also fell over the time period, in conjunction with new information on their potential harmfulness for typical AMI patients.

As the bottom panel of the Table shows, substantial increases also occurred in the use of surgical interventions such as angioplasty, bypass surgery, and cardiac catheterization. For example, cardiac catheterization was performed acutely on 3 percent of heart attack patients in 1975 but over

40 percent of heart attack patients in 1995. We analyze trends in the use of invasive cardiac procedures in more detail in the next sections of this paper.

The Table demonstrates that even technologies that were well-known in the mid-1970s diffused widely over the subsequent two decades. Comparing Tables 3-5, for example, shows that even though beta blockers were developed in the 1960s, their use more than doubled between the mid-1970s and the mid-1990s. Changes in the perceived effectiveness of these technologies, new literature on actual effectiveness, and other changes in the medical environment clearly resulted in substantial changes in medical practice.

We also reviewed the medical literature to estimate the effect of these various interventions on acute AMI mortality. Table 6 reports the estimated effects on relative mortality, along with confidence intervals, summarized from a variety of clinical trials and meta-analyses. Virtually all studies reported relative risk reductions (odds ratios) on case fatality rates.[8] Table 7 shows our estimates of the absolute mortality benefits of the changes in use of these technologies, extrapolated from their reported relative risk effects.[9]

A number of caveats apply to our results. First, most of the trials were conducted in middle-aged males without very serious comorbid diseases, so generalizing to all AMI patients requires some assumptions about the effects of treatment in other populations. There is some evidence from

---

[8]Most studies reported the effect of treatment on "case fatalities" as their principal treatment effect estimate, usually defined as 30-day mortality. However, some studies examined in-hospital mortality, and a few examined longer-term outcomes.

[9]We standardized the reported rates to 30-day mortality effects by applying the relative mortality reductions reported in the studies to population estimates of a baseline 30-day mortality rate in patients hospitalized with AMI of 22 percent (the 1975 case-fatality estimate for hospitalized AMI patients).

a few trials in the elderly that effects may actually be larger for this group, mainly because the baseline mortality rates are higher. Our "best-guess" estimates assume proportional effects in all AMI patients. Second, physician acumen in allocating treatments to particular patients and in determining the appropriate timing of interventions may also play an important role in the effectiveness of care. We do not account for improvements in acumen over time, but it is likely that accumulating experience with the technologies would increase their effectiveness. Third, as technologies diffuse more widely, it is possible that they would be used in more "marginal" cases, where benefits are smaller (McClellan, 1996). This effect may offset the experience effect, but again there is no easy way to quantify its magnitude. Finally, not all trials of particular treatments were conducted with a particular pattern of use of all the other treatments. For example, one might expect a smaller effect of heparin (which reduces blood clotting) in patients who are also receiving aspirin (which also limits blood clotting). In deriving our population estimates and ranges, we have tried to take such interactions into account, based on empirical evidence where it is available and based on reasonable clinical considerations otherwise. The resulting "adjusted" estimates of the acute mortality benefit[10] are reported in the third column of Table 7.

The fourth column of Table 7 reports the change in use rates (in percentage points) for each

[10]Some prior studies (for example, TIMI-2) included treatment arms that allowed estimation of interaction effects of certain treatments (for example, beta blockers and thrombolytics). These studies generally have shown that the combined effects of the interventions we study have less than fully-additive effects. Where such evidence is not available, we used clinical considerations about mechanisms of action. In particular, for our "best-guess" estimates, we assumed that the use of aspirin, beta blockers, and thrombolytics (key technologies for anticoagulation, cardioprotection, and reperfusion) would lead to a 50 percent reduction in the effects of other technologies with similar mechanisms of action, if those effects were estimated in studies that did not use these treatments. The adjusted effect estimates account for this joint diffusion of technologies.

of the technologies. The remaining columns of the Table report shares of acute mortality improvements explained by changes in the use of each treatment.

All of the estimated shares are based on our adjusted benefit estimates. The share calculations are based on a total reduction in acute mortality from 22 percent to 12 percent. In other words, if survival conditional on hospitalization with a heart attack had not changed between 1975 and 1995, approximately 30,000 more heart attack patients would have died in 1995. In attributing the mortality reduction to particular treatments, Estimate 1 assumes that only five of the technologies studied have nonzero mortality effects: beta blockers, aspirin, thrombolytics, ACE inhibitors, and primary PTCA.[11] The clinical trial evidence on the effects of these treatments is strong, and so this is our most conservative "best estimate." Estimate 2 includes our best estimates of the effects of the other technologies, based on somewhat weaker and unsettled clinical evidence. Finally, the "Upper" and "Lower" estimates provide extreme bounds on the estimated effects of the treatment changes. They are based on the upper (most effective) and lower (least effective) 95% confidence limits on the estimated treatment effects reported in published meta-analyses.

Table 7 shows that three drug therapies -- aspirin, thrombolytics, and beta blockers -- resulted in the largest improvements in heart attack mortality. For example, beta blocker use increased from 20 percent to about 50 percent of AMI patients during this period. Based on our best estimate of the average reduction in acute mortality from beta blockers (1.8 percentage points), this change in AMI treatment accounted for approximately 5 percent of the total acute mortality reduction for heart attacks, or approximately 1500 fewer deaths in 1995. Similarly, the diffusion of thrombolytics

[11]We assume that primary PTCA is used as an alternative to thrombolytics; in practice, relatively few patients receive both.

resulted in approximately 3300 fewer deaths, and aspirin (which became much more widely used between 1975 and 1995) resulted in approximately 6900 fewer deaths. Some recent studies of calcium-channel blockers suggest that they increase mortality for AMI patients. Increased use of these drugs suggests a slightly *higher* mortality rate in 1995 compared to 1975, although the substantial decline in calcium-channel blocker use since 1985 has limited this effect. Increased use of cardiac procedures, in particular the diffusion of primary angioplasty as an alternative to thrombolytic drugs for reperfusion, also accounted for some of the mortality reduction.[12]

Taken together, our estimates imply that changes in the medical treatments used in the acute management of AMI account for approximately 55 percent of the reduction in mortality that has occurred in AMI cases between 1975 and 1995, with the bulk of this improvement (50 percent) coming from pharmaceuticals. If we restrict our analysis to the five technologies described above for which the evidence on treatment effects is strongest, we obtain a slightly smaller estimated share explained (45 percent, with 42 percent coming from pharmaceuticals). Even our most conservative estimates of the mortality improvement resulting from acute treatments suggest that they account for around 20 percent of the observed improvement in mortality.

We also reviewed the more limited evidence on other sources of improvement in acute mortality over time. Though changes in monitoring methods appear to have been relatively important sources of mortality improvements in the 1960s and early 1970s (Goldman, 1984), coronary care units with close cardiac monitoring of heart attack patients had largely diffused by the mid-1970s. These CCU technologies support rapid detection and treatment of irregular heart

---

[12]The estimated mortality effects of these procedures are limited; however, there is considerable evidence that they have had a larger incremental impact on the quality of life of AMI patients.

rhythms and other serious complications. But because the vast majority of cardiac patients were being monitored by 1975, CCU monitoring has probably not played a major role in the acute mortality improvements since that time. The use of right-heart (pulmonary artery) catheterization for functional assessment in CCUs increased between 1975 and the late 1980s, and then appears to have declined modestly after 1990. Use of these devices is controversial, and there is no clear evidence that they improve survival. Thus, changes in cardiac monitoring have probably not resulted in any significant mortality improvements between 1975 and 1995.

Changes in pre-hospital care. Changes in pre-hospital care comprise another potential source of acute mortality improvements. Though far fewer studies have been reported, they do not suggest that pre-hospital care has accounted for much of the improvement in acute mortality. For example, studies of 1975 and 1990 AMI patients have found similar rates of ambulance use, and only modest increases in the availability of advanced cardiac life support (ACLS). Emergency 911 systems and (recently) enhanced 911 systems have become more widely available, and the content of ACLS procedures has evolved, but several studies have failed to document improvements in mortality following activation or enhancement of 911 systems. In the last several years, time between hospital arrival and the delivery of key AMI treatments (thrombolytics, primary angioplasty) appears to have declined. Reductions in "door to needle" time may reduce mortality; thrombolytic efficacy is linearly related to time between attack occurrence and drug treatment. But no reports exist on average times to reperfusion treatment. Taken together, it is likely that improvements in pre-hospital care and reductions in time to treatment have led to a modest improvement in AMI mortality, perhaps 5 percent to 10 percent, but this conclusion is speculative.

The factors we have described – changes in AMI patient characteristics, changes in acute treatment, and changes in pre-hospital care – appear to explain approximately 80 percent of the total improvement in acute mortality for heart attacks that occurred between 1975 and 1995. The remaining 20 percent may be the result of other technologies that we have not studied in detail, improvements in physician acumen in applying technologies, differential diffusion in subgroups of heart attack patients (with differential effects), and miscellaneous other factors. Within the 80 percent explained, acute treatments for AMI, and especially pharmaceutical treatments, are responsible for the bulk of the mortality reductions. Diffusion of invasive cardiac procedures, innovations in pre-hospital care, and more favorable characteristics of heart attack patients on admission have been responsible for small shares of the mortality improvements.

Post-acute treatment and secondary prevention. Published studies are also inadequate for more than speculative discussion of the factors responsible for improvements in post-acute mortality for heart attack patients. Because the complications of heart attacks -- including heart failure and chronic ischemic damage to the heart muscle -- are responsible for more deaths than heart attacks alone, the long-term improvements in mortality may be even more substantial than the acute improvements. Many innovations have occurred in the treatment of patients with substantial damage to their heart from the attacks, including expanded cardiac rehabilitation programs as well as drug therapies such as ACE inhibitors and anticoagulation therapy. The number of heart attack patients surviving with impaired function is clearly increasing, and these treatments have been shown to reduce mortality in patients with heart failure. However, few studies exist that quantify the effects of long-term therapies for heart failure patients. The best evidence exists for ACE inhibitors, but limited quantitative data on the changes in heart failure prevalence after heart attacks makes it difficult to quantify these important effects.

The same is true about secondary prevention of AMI through diagnostic procedures for risk stratification, risk factor counseling, pharmacologic therapies, and invasive procedures. Once again, studies show that many of these techniques result in significant reductions in long-term mortality after heart attacks, but we do not have data on changes in utilization or efficacy of these therapies for populations of heart attack survivors.

Further, it is likely that these treatments have important interactions with the changes in acute treatment of AMI. For example, AMI patients are now more likely to have blood flow to the heart restored acutely through thrombolytic drugs or primary angioplasty, and then are less likely to have subsequent blockages develop in the same or different coronary blood vessels because of use of cholesterol-lowering drugs and aspirin.

Taken together, the factors discussed here suggest that innovations in each of primary prevention, acute and post-acute management, and secondary prevention have led to substantial reductions in acute and long-term AMI mortality. We cannot quantify each of the components of improved long-term health, but medical interventions appear to be particularly important. Among these medical interventions, increased use of some key pharmaceutical agents -- particularly aspirin, thrombolytics, and beta blockers -- has led to the largest reductions in heart attack mortality.

III. The Costs and Benefits of Heart Attack Care[13]

Understanding the aggregate benefits of new technologies does not answer all of the questions we want to ask. We are also interested in the cost of these interventions, and how the costs relate to the benefits. These questions cannot be answered with the aggregate data. To address these issues, therefore, we use two more detailed sources of data.

The first data set is a complete record of detailed services, charges, demographic information, and discharge abstracts for all heart attack patients (patients discharged with a principal diagnosis of ICD-9 CM codes 410.00-410.99) admitted to one particular major teaching hospital (which we term MTH) between 1983 and 1994. Every specific billable service that the hospital provided is reported in the data. We restrict the sample to those patients for whom the observed heart attack was their first at this hospital, roughly 300 episodes annually.[14]

The second source of data is Medicare claims records for all elderly patients with a heart attack between 1984 and 1991. The Medicare claims records contain much less detail on services received than our hospital-specific service data; only major procedures and days in the hospital are reliably coded. However, the Medicare data have two important advantages relative to the MTH data. First, because Medicare is the primary payer for the vast majority of elderly Americans, we are able to construct comprehensive estimates of expenditures on medical care for almost all elderly

[13] The analysis in this section and the next draws heavily on Cutler, McClellan, Newhouse, and Remler (1996).

[14] We do not know if the patient had an earlier heart attack elsewhere. However, we do know if they were transferred to MTH from another hospital. We have experimented with restricting the sample to non-transfers, without important effects on the results.

AMI patients from 1984 to 1991. This is roughly 230,000 patients annually. We limit our analysis to hospital costs, since hospital costs comprise the predominant expense in caring for AMI patients. Second, one can link Medicare data to Social Security death records and thereby determine survival outcomes.

We date the onset of the heart attack at the first admission to a hospital with a heart attack diagnosis -- the box on the left in Figure 3. As noted above, a person who suffers a heart attack will almost always be admitted to a hospital, unless he or she dies before reaching one (in which case the cost of treatment is not very interesting), because the initial treatments for AMI must all be administered in an inpatient setting. While they survive, patients may receive care for their heart attack, in and out of hospitals, over the following months. For example, patients may receive tests or invasive diagnostic procedures in the initial hospital admission, and be readmitted for additional tests or invasive procedures later on. We group all care received within 90 days of the initial heart attack in the same heart attack episode. All of our subsequent results are based on heart attack episodes.

We begin by examining the aggregate mortality experience of people suffering a heart attack, from the Medicare data. Figure 4 shows cumulative mortality rates for the elderly for various time periods after a heart attack: one day; 90 days; and 1 through 5 years. Substantial reductions in mortality rates following a heart attack have occurred in the elderly. Mortality during the initial hospital stay fell nearly two percentage points. Mortality at one year fell by considerably more, five percentage points. Because the mortality data only extend through the end of 1992, we cannot measure mortality rates in 1991 for time periods longer than a year. Still, the data through 1987 suggest declines in cumulative mortality rates at periods beyond one year as well.[15]

As noted above, medical care may be only one factor in this mortality improvement; risk factor modification or environmental changes may also be important. One way to judge the importance of these factors is to consider increased life expectancy for people with heart attack compared to the overall elderly population. To the extent that risk factor changes or environmental factors affect all of the elderly equally, the difference in mortality reductions between heart attack patients and the general elderly population will be a more accurate indicator of the benefits of medical care than the reduction in heart attack mortality alone.[16] When we compare the increase in survival for heart attack patients relative to the overall elderly population, we find an increase in life expectancy in the overall elderly population only half as large (4 months). Thus, medical care likely has some effects on heart attack survival.

The fact that mortality has been falling after a heart attack confirms the evidence from the medical literature above. The fact that mortality has been falling so rapidly in the *first day* after the

---

[15] It is important to recognize that these changes represent changes in *average* health following a heart attack. A substantial amount of evidence suggests that the *marginal* amount of medical care - even care for heart attacks -- provides benefits at relatively high cost (McClellan, McNeil, and Newhouse, 1994; Cutler, 1995; McClellan, 1995; Cutler and Staiger, 1996; McClellan, 1996; McClellan and Newhouse, 1997; Newhouse and McClellan, 1998). For our work, we care about average health benefits, but in other circumstances, we might be more concerned about marginal benefits.

[16] This methodology is not exact. Reductions in aggregate mortality resulting from some factors (for example better control of blood sugar for diabetics) will reduce mortality for heart attack sufferers more than mortality for the general population, while reductions in aggregate mortality from other factors (for example better cancer therapy) will have a smaller effect on heart attack patients than the general population. In both of these cases, the difference in mortality reductions between heart attack patients and the overall population will include more than just the effect of heart attack treatments, but the sign of the bias is unknown.

heart attack strongly implies that the set of early interventions -- thrombolytic therapies, better 911 systems, improved EMT care -- have had a particularly large effect on mortality. This again confirms our findings from the medical literature.

A. Increased Survival After a Heart Attack

To examine the importance of these mortality reductions for overall health of people with an AMI, we turn them into an increase in life expectancy after a heart attack. Estimating life expectancy from mortality rates is not trivial; a number of imputations are involved (Cutler, McClellan, Newhouse, and Remler, 1996 discuss this in more detail). In the interest of brevity, we omit the details here.

The first column of Table 8 shows life expectancy after a heart attack. In 1984, the average person with a heart attack lived 5 years and 2 months. By 1991, the average heart attack sufferer lived 5 years and 10 months, an increase of 8 months.

The benefits of heart attack treatments might show up in improved quality of life as well as length of life. But morbidity after a heart attack is difficult to measure; few studies have evaluated the detailed functional capabilities (can people walk up a flight of stairs without pain?) of people with a heart attack over time.[17] We thus stick with the mortality benefits of changes in heart attack therapies. Since Table 2 showed that morbidity for heart attack survivors was likely improving over time, this should bias us against finding large benefits of heart attack treatments.

B. The Costs of AMI Treatment

---

[17] See Cutler and Richardson (1997) for one such attempt.

In addition to estimating the benefits of heart attack care, we can also estimate its costs. Figure 5 shows the average cost of treating a heart attack between 1984 and 1991, based on the Medicare data. The third and fourth columns of Table 8 shows the level and cumulative change in costs over time. We report costs in 1991 dollars (adjusted using the GDP deflator). The cost of a heart attack has increased from about $11,000 in 1984 to about $15,000 in 1991, for a real increase of 4 percent annually.

Table 9 shows more information on these costs. The first row shows total hospital spending on heart attacks. Heart attack spending increased from $2.6 billion in 1984 (in 1991 dollars) to $3.4 billion in 1991. The second row shows the incidence of heart attacks in the Medicare data. Heart attack incidence has actually been falling over time, in part because of improved primary and secondary prevention. As a result, cost per heart attack, shown in the third row of the table, has been increasing even more rapidly than total heart attack costs.[18]

What can explain this increasing cost of heart attack care? The next rows of Table 9 show Medicare reimbursement for our different treatment regimens over time. Reimbursement conditional on a treatment regimen was relatively constant or even falling in real terms over this period. This is particularly true for angioplasty, where reimbursement fell 6 percent annually. This large reduction was by design; angioplasty reimbursement was reduced in 1986 as Medicare administrators cut payments to more accurately reflect the estimated cost of performing the treatment. Catheterization-only payments were also reduced, as more catheterizations were performed during the initial hospital

[18] The numbers in Table 9 do not match those in Table 8 precisely because the data in Table 8 are adjusted for the average demographic mix of the heart attack population over the 1984-91 period, while the numbers in Table 9 use the population of heart attack patients that year. As a comparison of the Tables indicates, the demographic adjustment is relatively unimportant.

stay rather than on a subsequent admission. Reimbursement for medically managed heart attacks or bypass surgery increased marginally (see Cutler and McClellan, 1996, for more details.) The MTH accounting cost data, shown in the last rows of the Table, generally show the same pattern, although these data include the non-Medicare population as well. Thus, price increases per type of service received do not appear to explain the growth of spending.

In contrast to the relatively flat prices for given therapies, there has been a dramatic increase in the use of more intensive therapies over time. Figure 6 shows the use of intensive surgical therapy for heart attack patients in the Medicare data. Use of cardiac catheterization rose from 10 percent in 1984 to over 40 percent by 1991. Bypass surgery rates increased from 5 to 15 percent, and angioplasty rates went from 1 to 15 percent.

Medicare pays more for more intensive care than for less intensive care. As a result, the increase in the intensity of medical treatment has had large effects on medical spending. Indeed, our data suggest that *all of the growth of costs for heart attack treatment can be explained by the increase in the intensity of treatment, rather than an increase in the cost of a standard type of care.*

C. Cost-Benefit Analysis of Heart Attack Treatment

To compare the costs and benefits of heart attack treatment, we need a dollar value for a year of life. Estimating the worth of a life is very controversial (Viscusi, 1993). We use as a central estimate a value per lifeyear of $25,000. This estimate is low compared to others in the literature; for example, Tolley et al. (1994) suggest a value of a lifeyear of $75,000 to $150,000. Thus, we are likely to find less beneficial care than others would suggest. The second column of Table 8 shows the change in the value of health for heart attack survivors implied by this estimate. Between 1984 and 1991, the value of additional life increased by nearly $15,000.

Comparing the second and fourth columns of Table 8, we find that the increase in the value of additional life ($15,000 by 1991) is greater than the increase in costs of heart attack care ($4,000 by 1991). In other words, we are better off for having spent our money on heart attack care than we would have been if the money had been spent elsewhere.

This is an extremely important result; if it generalizes to other medical treatments, it implies, for example, that the true "price" of medical care services has not been increasing nearly as rapidly as official indices suggest. We turn to this issue in the next section.

IV. Implications: A Price Index for Heart Attack Care

The finding of a positive benefit-cost difference for heart attack care implies that the real "price" of medical care has been falling over time. To see this, we need to discuss price indices in somewhat more detail.[19] We distinguish between two price indices:

A. The Service Price Index

The first price index is a *Service Price Index.* This is the index used in the current BLS Consumer Price Index and Producer Price Index for medical care. Methodologically, this price index is constructed by choosing a fixed basket of goods and then pricing that same basket over time. We term this a service price index because it focuses on a given set of medical services, as opposed to

---

[19] For more discussion of appropriate price indices for medical care, see Triplett (1997) and Shapiro and Wilcox (1996).

the value to consumers of medical care.

For example, to calculate the hospital component of the CPI, the traditional Bureau of Labor Statistics index priced charges for six hospital services at each hospital: two room services (for example, charges per day for semi-private rooms and medical intensive care unit [ICU] rooms), three other inpatient services (for example, operating room time or electrocardiograms [ECG]) and one outpatient service (for example, outpatient ECG). These services are then aggregated into a hospital index.[20]

The first row of Table 10 shows the growth of the real (relative to the GDP deflator) medical care CPI from 1983 to 1994. Over this time period, the real medical CPI rose by 3.4 percent annually. In the next row, we replicate this analysis using heart attack treatments at MTH. The real CPI for heart attacks at MTH grew at an annual rate of 3.3 percent, almost the same as the overall medical care CPI.

Very few payers pay charge (or list prices) for medical care. Discounts from charges are the norm, especially for hospital care, and the pricing of medical care needs to account for this. To adjust for this factor, we formed an alternative price index based on the cost of medical care in MTH, rather than its charge. For the average payer, costs are more likely to be an accurate reflection of average prices than will charges. As the next row shows, a CPI based on costs instead of charges grew about a percentage point less each year, for an annual increase of 2.4 percent.

The traditional medical care CPI does not change the quantity of goods that are priced over time. For example, the hospital room component always priced the cost of one day in a hospital, independent of how long patients actually stay in the hospital. A more accurate price index would

---

[20] See, for example, Bureau of Labor Statistics (1992) and Ford and Sturm (1988).

price the basket of goods that a typical patient is actually receiving over time. Then, as some services are substituted for other services, the price index would reflect that substitution. The next row of Table 10 shows the growth of such a price index. We reweight the basket of goods that is provided annually. The growth of the index is much lower in this case, only 0.7 percent per year.

The final issue in the service price index is whether we want to price itemized medical services, or whether we would rather price a more aggregated "treatment regimen", as in Figure 2. Pricing treatment regimens may be more relevant than pricing a particular bundle of services; after all, it is much more natural to think that producers are supplying "bypass surgery at the current standard" than the particulars of surgery in any year. The next row of Table 10 shows the price index based on treatment regimens. We can form this index using either the MTH data or the Medicare data. In both cases, the results are similar; the price index increases about 0.5 percent per year. The difference between this estimate and the official growth of the CPI is large; while the current CPI is increasing nearly 3.5 percent per year, our preferred service price index is increasing only 0.5 percent per year relative to the overall GDP deflator.

The Bureau of Labor Statistics has recently revised the CPI along the lines of our Treatment Regimen Price Index. The change was in part because many payers now reimburse medical care at the level of treatment regimens, and in part because it was perceived to be a more accurate basis for pricing. This change in the CPI index may have important effects on measured inflation in the medical sector.

B. The Cost of Living Index

An alternative price index to the Service Price Index is a *Cost of Living Index*. Where the service price index asks about the cost of goods sold, the cost of living index asks about changes in the price of what consumers receive. The major difference between these two indices is medical care quality. A higher quality bypass surgery operation may cost the same to produce but would be worth more to consumers. This additional value is an effective price reduction to consumers.

Formally, we define the change in the cost of living index as the increased spending on medical care over time less the additional value of that care. If medical care increases in cost without much improvement in health, that would be an increase in the cost of living. If medical care increases in cost but the value of that care rises over time, the cost of living index would be falling.[21]

The key to forming this index is to note that the cost and benefit of medical care are exactly what we calculated in the previous section. There, we showed that the benefits of heart attack care were greater than its additional costs. The implication is that the cost of living index for heart attack care is actually *falling* over time, not rising. The last row of Table 10 shows our calculation of the cost of living index. Our best estimate is that the cost of living fell by 1.1 percent annually over the 1984 to 1991 period. This finding is a direct consequence of our positive benefit-cost differential.

This calculation is striking.[22] Where current price indices for medical care are increasing by

---

[21] Formally, the cost of living index is the change in the expenditure required to produce a given level of utility. We can decompose this into two parts: the additional resources required by the medical sector, and the health benefits of medical care:

$$\Delta\begin{pmatrix} \textit{Quality- Adjusted Cost} \\ \textit{of Medical Services} \end{pmatrix} = \begin{pmatrix} \textit{Increase In} \\ \textit{Medical Spending} \end{pmatrix} - \begin{pmatrix} \textit{Dollar Value Of} \\ \textit{Improved Health} \end{pmatrix}$$

Measuring the change in the cost of living involves estimating these two terms.

[22] For additional empirical applications, see Griliches and Cockburn (1996), Ellison and Hellerstein (1997), Berndt, Frank, and Busch (1997), Shapiro and Wilcox (1997), and Cockburn (1997).

3 to 4 percent per year above general inflation, our best estimate of a quality-adjusted price index is falling by about 1 percent per year. And even if we ignore quality improvements, our preferred estimate of the price of heart attack treatments is that they are rising by perhaps 0.5 percent per year relative to other prices in the economy.

V. Managed Care and the Treatment of Heart Attacks[23]

The final issue we explore is the effect of managed care on the treatment of heart attacks, and on the benefit-cost analysis of the previous sections. The $1 trillion American health care services industry is rapidly changing its structure. Traditionally, the provision of medical services and the payment for those services were separate industries. Patients and providers decided on appropriate treatments, and insurers paid the bill. Increasingly, however, medical services and insurance are becoming integrated, and care is being more regularly "managed". Insurers commonly use financial incentives to limit utilization, place restrictions on the services that may be provided, and form restrictive networks to bargain for lower prices from providers. Managed care has become the norm among the privately insured population. Where only one-quarter of the privately insured population was in managed care in 1987, three-quarters of the privately insured population is enrolled in managed care today (Gabel et al., 1989; Jensen et al., 1997).

In principle, managed care may be good or bad for heart attack treatments. While much

---

[23] The analysis in this section draws heavily from Cutler, McClellan, and Newhouse (1997).

popular discussion has focused on the potential for managed care to limit expensive treatments, it may also be the case that by getting people into the medical care system earlier, managed care increases the use of some technologies. It might also reduce the cost of the same medical care treatments. Ultimately, this is an empirical question.

We use two sources of data to examine the impact of managed care on heart attack treatment. The first is the complete claims records of a large firm in the Massachusetts area for the 30 months from July 1993 through December 1995 (the "firm data"). The firm has about 200,000 covered lives in its non-retiree population. The firm offers a traditional indemnity policy, a preferred provider organization, and several HMOs, which we generally group together. There are about 70,000 to 100,000 people in the indemnity and HMO policies, and about one-quarter that number in the PPO. For each plan, we know inpatient, outpatient, and prescription drug spending for all enrollees. We also know major procedures provided. We can thus look at total spending by plan and the use of particular forms of care.

Our second source of data is the complete set of inpatient claims for people admitted to hospitals in Massachusetts in fiscal years 1994 and 1995 (the "state data"). Beginning with calendar year 1994, hospitals provided Social Security Numbers for the patients they admitted, so that admissions can be linked (even across hospitals) to form an episode of care. In the state data, we have several thousand heart attack episodes in indemnity policies, PPOs, and HMOs. The state data have more heart attack patients than the firm data, so they are better for analyzing the relation between type of insurance and inpatient care received. The state data do not contain reimbursement information, however, so we cannot look at spending differences with these data.

To examine differences in spending on heart attacks, we form 90-day episodes of heart attack treatment, in the same fashion as our previous analysis. The upper panel of Table 11 shows summary statistics on reimbursement for heart attacks, using the firm data. The first column shows average reimbursement for all patients. Heart attacks are expensive; average reimbursement in the indemnity policy is $38,501 in the first 90 days. Reimbursement is much lower in the other plans. Average reimbursement in the PPO is only 69 percent as high as in the indemnity policy ($26,483), and reimbursement in the HMO is only 61 percent as high ($23,631).

The next four columns of Table 11 show reimbursement and the share of patients by treatment regimen.[24] Reimbursement differences within treatment regimens mirror the overall reimbursement differences. In each case, reimbursement in the HMOs is only 50 to 60 percent as high as reimbursement in the indemnity policy. In contrast, the share of patients receiving different treatment regimens is roughly the same in the different plans. In the firm data, managed care patients are slightly *more* likely to receive intensive surgical procedures than are patients in the indemnity insurance policy; in the state data, managed care patients are slightly less likely to receive intensive surgical procedures than are patients in indemnity insurance. The final column of Table 11 shows that, adjusted for differences in the share of patients receiving different treatments, reimbursement in the HMOs is still only 55 percent of reimbursement in the indemnity policy.

Thus, it appears that essentially all of the cost differences across plans results from differences in reimbursement conditional on a treatment regimen rather than a different type of care provided. We formalize this finding in Table 12, where we estimate regression models for treatments and reimbursement as a function of the type of insurance the individual is enrolled in.

---

[24] We do not show statistics for the PPO because the number of heart attack patients is so small.

We also include several control variables, including five year age dummy variables, a dummy variable for men, dummy variables for region in the state,[25] and the logarithm of median household income in the person's zip code, taken from the 1990 Census.

The first two columns show ordinary least squares estimates of the probability that a patient receives cardiac catheterization or coronary revascularization.[26] Men are more likely to receive intensive treatment than are women. Income is not related to treatment intensity, but people from MSAs are more likely to receive these procedures than are people outside of MSAs (not reported). The insurance variables are similar to the means in Table 11. Controlling for demographics, HMO patients are a bit less likely to receive intensive procedures than are patients in indemnity insurance. This effect is statistically significant for catheterization but not for revascularization. The magnitude of these effects is relatively small however – about 2 to 3 percentage points.

The third column of the Table shows the effect of insurance on reimbursement conditional on the treatment regimen. In contrast to the results for treatment differences, we find large effects of insurance on reimbursement for a given treatment regimen. The coefficient on the HMO dummy variable implies that HMOs pay 44 percent less than indemnity insurance (exp(-.58)), and this is statistically significant.

The implication of these results is that essentially all of the difference between managed care and traditional insurance is on the prices paid for medical care, not the amount of medical care

---

[25] In the firm data, we divide people into those living in Boston, those living in another MSA, and those living outside of an MSA. In the state data, we include a dummy variable for different MSAs, and a dummy variable for people living outside of an MSA.

[26] We use ordinary least squares estimates to be compatible with our later instrumental variables estimates. Logit models of treatment regimens yield very similar results.

received.

Although this result is clear in our data, we want to draw some caution to it, on several grounds. First, the data are from only one state, and managed care is likely to differ across the country. Second, heart attacks probably involve less discretion in the choice of treatment than other diseases such as depression or common outpatient care. This is because managed care rarely provides its own heart attack treatment; it typically contracts with cardiologists and cardiovascular surgeons who also see non-managed care patients. Indeed, other studies show larger differences in the treatment of depression across insurance plans than we find here (Frank, Berndt, and Busch, 1997). Finally, we suspect that the effect of managed care varies over time, so that more recent data could yield different conclusions than we found in our time period.

VI. Conclusions

Our results suggest several important conclusions. First, while we pay more for medical care than we used to, we get more in return than we used to. Our review of the medical literature and our examination of medical records both document a large role for medical care in improving health of heart attack patients. In our sample of Medicare beneficiaries with a heart attack, we estimate that for an additional cost of $4,000 per heart attack patient, we have extended life by an average of 8 months. Even at very modest estimates of the value of a lifeyear, it is hard to escape the conclusion that the additional spending on heart attacks has been worth the cost.

This conclusion has direct implications for productivity and price measurement in the medical sector. Receiving more in improved health than we pay in treatment costs implies that medical care is a more productive investment than the average use of our funds outside the medical sector. And it implies that a true cost-of-living index for heart attack care -- a price index for health after a heart attack -- is falling over time, where conventional medical care price indices have suggested a rapid rise.

The important question is whether our results generalize to other types of medical care. We do not know the answer to this question. Heart attacks are clearly different from other conditions: they are acute, and they are very technologically intensive. In a medical care system accused of having a bias towards high-tech treatment of very severe illness, this suggests heart attacks may be a best case analysis. On the other hand, there is a longstanding literature suggesting only a small role for acute interventions in improved cardiovascular disease health. The fact that we find such a large role for medical care in the treatment of a condition commonly believed to respond more to behavior than to medical inputs suggests that our findings might be indicative of the medical sector more broadly.

But perhaps most importantly, our results provide a framework for analyzing these issues in the future. Measuring the productivity of the medical care sector – and the service sector more generally – has been a longstanding problem in national income accounting. The methodology in this paper suggests a way to tackle this fundamental issues. Along with other research on the price and output of the medical sector (Frank, Berndt, and Busch, 1997; Fischer and Hellerstein, 1997; Shapiro and Wilcox, 1997; Triplett, 1997), this provides guidance for how to learn about these issues in the years to come.

References

Braunwald, Eugene, *Heart Disease: A Textbook of Cardiovascular Medicine*, Philadelphia: Saunders, 1997.

Bureau of Labor Statistics, "The Consumer Price Index", Chapter 19 in *BLS Handbook of Methods*, Bulletin 2414, September 1992.

Cockburn, Iain, "Price Indices for the Treatment of Arthritis", mimeo, 1997.

Cutler, David M., "The Incidence of Adverse Medical Outcomes Under Prospective Payment", *Econometrica*, February 1995, 63(1), pp. 29-50.

Cutler, David M., Mark McClellan, Joseph Newhouse, and Dahlia Remler, "Are Medical Prices Declining?" NBER Working Paper No. 5750, September 1996.

Cutler, David M., and Elizabeth Richardson, "Measuring the Health of the United States Population", forthcoming, *Brookings Papers On Economic Activity: Microeconomics*, 1997.

Cutler, David M., and Doug Staiger, "Measuring the Value of Medical Progress", mimeo, December 1995.

Ellison, Sara Fisher, and Judith Hellerstein, "The Economics of Antibiotics: An Exploratory Study", mimeo, May 1997.

Ford, Ina Kay and Philip Sturm, "CPI Revision Provides More Accuracy in the Medical Care Services Component", *Monthly Labor Review,* April 1988.

Berndt, Ernst R., Richard Frank, and Susan Busch, "Prices for Treatment of Depression", mimeo, 1997.

Gabel, Jon, Steven DiCarlo, Steven Fink, and Gregory de Lissovoy, "Employer-Sponsored Health Insurance in America", *Health Affairs*, Summer 1989, 116-128.

Isselbacher, Kurt, et al., *Harrison's Principles of Internal Medicine, 13th Edition,* New York: McGraw Hill, 1994, p. 1115.

Jensen, Gail A., Michael A. Morrisey, Shannon Gaffney, and Derek K. Liston, "The New Dominance of Managed Care: Insurance Trends in the 1990s", *Health Affairs*, January/February 1997, 125-136.

Griliches, Zvi, and Iain Cockburn, "Generics and New Goods in Pharmaceutical Price Indexes", *American Economic Review*, December 1994, 84(5), pp. 1213-1232.

Heidenreich, Paul, and Mark McClellan, "The Consequences of Changes in Treatment of Acute

Myocardial Infarction, 1975-1995: A Literature Review and Synthesis," mimeo, 1997.

McClellan, Mark, "Changes in the Marginal Value of Medical Care", mimeo, 1996.

National Center for Health Statistics, "Vital Statistics," 1997.

Newhouse, Joseph P., and Mark McClellan, "Econometrics in Outcomes Research", *Annual Review of Public Health*, 19, 1998, 17-34.

Shapiro, Matthew, and David Wilcox, "Causes and Consequences of Imperfections in the Consumer Price Index", mimeo, 1996.

Triplett, Jack E., "What's Different About Health? Human Repaid and Car Repair in National Accounts", mimeo, May 1997.

Viscusi, W. Kip, "The Value of Risks to Life and Health", *Journal of Economic Literature*, 31 (4), 1912-1946.

Table 1: Leading Causes of Death in the United States, 1995

Cause	Death Rate (per 100,000)
Cardiovascular Disease	341.4
Diseases of heart	281.2
Cerebrovascular disease	60.2
Malignant Neoplasms	204.7
Chronic Obstructive Pulmonary Disease	39.9
Accidents and adverse effects	34.1
Pneumonia and influenza	31.8
Diabetes mellitus	22.5
HIV	16.2
Suicide	11.8
Chronic liver disease and cirrhosis	9.5
TOTAL	880.0

Source: National Center for Health Statistics (1997).

Table 2: Changes in Functional Status for People Reporting Having Been Diagnosed with Ischemic Heart Disease

Measure	1972	1981	1982	1991
Functional Limitations Resulting From IHD[*]				
Cannot perform usual activity	16.7%	15.5%	15.0%	8.6%
Can perform usual activity but limited in amount and kind	29.0	21.3	12.3	6.3
Can perform usual activity but limited in outside activities	6.6	5.2	8.4	7.6
Not limited or IHD not primary cause	47.8	58.0	64.3	77.5
Self-Reported Health Status				
Excellent	---	---	4.5%	5.2%
Very Good	---	---	12.2	12.1
Good	---	---	26.5	27.1
Fair	---	---	28.2	29.8
Poor	---	---	28.0	24.9

Note: Data are from the Health Interview Surveys. Self-reported health status was not asked prior to 1982.

[*] After 1981 the wording changed to: unable to perform major activity; limited in kind/amount of major activity; limited in other activities; and not limited.

Table 3: Dates of Introduction of Important Pharmaceuticals for Cardiovascular Care

Drug Class	Year of Innovation
Antihypertensives	1959
Beta blockers	1962
Calcium Channel Blockers	1971
ACE Inhibitors	1979

Note: The year of innovation refers to the first drug in the class. Other advances were made in later years.

Table 4: Dates of Introduction of Important Advances for Acute Treatment of Cardiovascular Disease

Treatment	Year of Innovation
Catheterization	1959
Bypass surgery	1968
Cardiac ICUs	1970s
Angioplasty	1978
Thrombolytics*	1980s

Note: The year of innovation refers to initial development. Other advances were made later.

* Developed in the 1970s but not applied in heart attack care until the 1980s.

Table 5. Use of Acute Interventions for Myocardial Infarction*

Therapy	1973-77	1978-82	1983-87	1988-92	1993-96
Pharmaceuticals					
Beta Blockers	20.6	41.5	47.5	47.3	49.8
Aspirin	15	14.1	20.1	62	75
Nitrates	55.8	83.1	93.2	---	---
Intravenous Nitroglycerin	29.1**	40.9	76.4	---	59
Heparin/anticoagulants	---	---	53	75	70
Calcium-Channel Blockers	0	0	63.9	59	31
Lidocaine	30	48.2	46.5	---	16.2
Other antiarrthymics	30.7	22.5	21.9	---	---
Magnesium	---	---	---	---	8.5
ACE inhibitors	0	---	---	---	56
Thrombolytics	0	0	9.3	24.5	30.6
Procedures					
Catheterization	3.1	5.2	9.8	34.9	42
Primary PTCA	0	0	0	---	9.1
Any PTCA	0	0	5.6	21	15
CABG	2.85**	5.7	8	10	9.5

Note: Based on literature review in Heidenreich and McClellan (1997).
* In hospital or 30 day use. ** Average of 1970 and 1979 values.

Table 6. Effects of Acute Interventions on Acute Mortality after Myocardial Infarction

Therapy	Odds ratio	Upper	Lower
Pharmaceuticals			
Beta Blockers	0.88	0.8	0.98
ASA	0.77	0.7	0.89
Nitrates	0.94	0.9	0.99
Heparin/anticoagulants	0.78	0.65	0.92
Calcium -Channel Blockers	1.12	0.92	1.39
Lidocaine	1.38	0.98	1.95
Magnesium	1.02	0.44	1.08
ACE inhibitors	0.94	0.89	0.98
Thrombolytics	0.75	0.71	0.79
Procedures			
Primary PTCA			
CABG			

Note: The table reports effects on mortality risk *reduction*, that is, estimates greater than one for relative risk imply reductions in risk. Data are based on literature review in Heidenreich and McClellan (1997).

Table 7: Estimated Acute Mortality Benefits of Changes in Acute Treatment of AMI

Therapy	Absolute Benefit*	Adjusted Benefit**	Change in Use, 1995-1975 (%)	Share of Mortality Reduction Explained (%) Estimate 1	Estimate 2	Upper	Lower
Pharmaceuticals							
Beta Blockers	0.021	0.018	29	5%	5%	9%	1%
Aspirin	0.042	0.038	60	23	23	30	11
Nitrates	0.010	0.008	30	0	3	5	0
Heparin/anticoagulants	0.040	0.008	4	0	1	2	0
Calcium-channel Blockers	-0.020	-0.015	31	0	-2	3	-5
Lidocaine	-0.060	-0.045	-15	0	7	0	0
Magnesium	-0.003	-0.003	8.5	0	0	7	0
ACE inhibitors	0.010	0.008	24	2	2	3	1
Thrombolytics	0.045	0.036	31	11	11	13	9
Procedures							
Primary PTCA	0.045	0.036	9.1	3	3	4	3
Other PTCA	0.010	0.008	15	0	1	6	0
CABG	0.010	0.008	6.7	0	1	3	0
Total				45%	55%	85%	20%

Note: Based on data analysis in Heidenreich and McClellan (1997).

* based on meta-analysis odds ratio and 1975 mortality of 22%. ** adjusted for interactions between therapies.

† % of 1995-1975 decrease in AMI case fatality rates explained by changes in use of each treatment. Estimate 1 assumes mortality effect for only beta-blockade, aspirin, thrombolytics, ACE inhibition, and primary PTCA. Estimate 2 assumes that the true benefit or harm for each drug equals the estimate from meta-analysis. "Upper" uses the favorable 95% confidence limit from meta-analysis of the mortality reduction for each drug. "Lower" uses the unfavorable 95% confidence limit, and assumes only aspirin, primary PTCA, thrombolytics and ACE inhibitors affect mortality.

Table 8: Life Expectancy And Cost Following a Heart Attack

Year	Life Expectancy (years)	Change in Life Value	Costs (dollars)	Change in Costs
1984	5 2/12	---	$11,123	---
1985	5 4/12	$2,821	11,638	$514
1986	5 4/12	3,277	11,980	856
1987	5 5/12	5,180	12,250	1,127
1988	5 6/12	7,799	12,746	1,622
1989	5 8/12	10,899	13,076	1,953
1990	5 9/12	13,637	13,681	2,558
1991	5 10/12	14,860	14,851	3,727

Note: The sample is all elderly Medicare beneficiaries with a new heart attack. Costs are in 1991 dollars.

Table 9: Technological Change and Expenditures in Cardiac Procedure Use, 1984-91

	Intensive Procedure Use			Average Hospital Reimbursement		
AMI Treatment	1984	1991	Annual Change*	1984	1991	Annual Change
Total Spending				$2.6 bn	$3.4 bn	3.9%
Number of Patients				233,295	227,182	-0.3%
Average Reimbursement				$11,175	$14,772	4.0%
Type of Treatment - Medicare						
Medical Management	88.7%	59.4%	-4.2%	$9,829	$10,783	1.3%
Catheterization Only	5.5	15.5	1.4	15,380	13,716	-1.6
Angioplasty	0.9	12.0	1.6	25,841	17,040	-5.9
Bypass Surgery	4.9	13.0	1.2	28,135	32,117	1.9
Type of Treatment - MTH						
Medical Management	65%	23%	-4.7	$13,900	$11,769	-1.8%
Catheterization Only	20	21	.1	15,290	15,105	-0.1
Angioplasty	3	30	3.0	16,124	18,441	1.5
Bypass Surgery	11	27	1.8	37,437	50,874	3.4

Note: Costs are in 1991 dollars, adjusted using the GDP deflator. Costs for MTH are an average of 1983-85 and 1992-94.

* Growth is average percentage point change each year.

Table 10: Summary of Price Indices

Index	Real Annual Percent Change
Service Price Indices	
Medical Care CPI	3.4%
Synthetic CPI for MTH - Charges	3.3
Synthetic CPI for MTH - Costs	2.4
Annually Rebased Price Index	0.7
Treatment Regimen Price Index	0.4/0.6
Cost of Living Index	-1.1%

Note: Service Price Indices are for the 1983-94 period, with the exception of treatment regimen price index for Medicare data (1984-1991) and Cost of Living Index (1984-1991). Growth of price indices is relative to the GDP deflator.

Table 11: Heart Attack Reimbursement and Treatment by Plan

Plan	Average Reimbursement (unadjusted)	Treatment Regimen				Average Reimbursement (adjusted)
		Medical Management	Cardiac Catheterization	Bypass Surgery	Angioplasty	
Average Reimbursement						
Indemnity	$38,501	$24,720	$47,105	$106,302	$44,542	$40,329
BC/BS PPO	26,483 [69%]	---	---	---	---	---
HMO	23,632 [61%]	14,475 [59%]	24,447 [52%]	55,826 [53%]	24,097 [54%]	22,048 [55%]
Treatment Shares - Firm Data						
Indemnity	---	56%	23%	7%	13%	---
HMO	---	53	16	14	17	---
Treatment Shares - State Data						
BC/BS and Indemnity	---	41%	19%	14%	26%	---
Non-HMO Managed Care	---	35	21	16	27	---
HMO	---	44	17	14	25	---

Note: Reimbursement is within 90 days of the initial heart attack.

Table 12: Estimates of the Effect of Insurance on Treatments and Reimbursement for Heart Attacks

	State Data		Firm Data
	Treatment Regimen		Reimbursement | Treatment
Variable	Cardiac Catheterization	Coronary Revascularization	ln(Reimbursement)
Insurance			
HMO	-.034**	-.025	-.578**
	(.017)	(.017)	(.060)
Non-HMO Managed Care	.018	-.008	---
	(.019)	(.020)	
Demographics			
Male	.039**	.053**	.057
	(.017)	(.017)	(.060)
White	-.132**	-.104**	---
	(.025)	(.025)	
ln(Median Income)	.034	.037	.184*
	(.028)	(.029)	(.103)
Previous Admission	.003	.000	.102*
	(.021)	(.022)	(.064)
Summary Statistics			
N	4,243	4,243	853
σ^2_ϵ	.217	.226	.635

Note: Care is all services provided within 90 days of the initial heart attack admission. All regressions include 5 year age dummy variables and region dummy variables. Standard errors are in parentheses.
* (**) Statistically significant at the 10% (5%) level.