HHS Public Access

Author manuscript

*Health Aff (Millwood)*. Author manuscript; available in PMC 2018 October 29.

Published in final edited form as:

*Health Aff (Millwood)*. 2005 ; 24(Suppl 2): W5R5–W517. doi:10.1377/hlthaff.w5.r5.

# Consequences of Health Trends and Medical Innovation for the Future Elderly

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## Abstract

Recent innovations in biomedicine seem poised to revolutionize medical practice. At the same time, disease and disability are increasing among younger populations. This paper considers how

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these confluent trends will affect the health status and health care spending of the elderly over the next 30 years. Because healthier individuals live longer, cumulative Medicare spending varies little with a beneficiary's disease and disability status upon entering Medicare. On the other hand, ten of the most promising medical technologies – as identified by biomedical experts — are forecasted to increase spending substantially, at a cost of $9,000 to $1.4 million per life-year. We conclude there is substantial technological risk in future spending by the elderly, and it is unlikely a "silver bullet" will emerge to both improve health and dramatically reduce medical spending.

The consequences for human health of recent breakthroughs in fundamental biology — including the landmark sequencing of the human genome — are impossible to predict with any certainty. However, the biomedical community appears confident that unprecedented advances in our ability to prevent, detect, and treat disease are within reach. If so, there will be striking improvements in population health, and, if one believes the most optimistic forecasts, a concomitant decrease in the total resources devoted to medical care.

This optimism must be tempered by some pressing demographic trends. The number of Americans 65 years or older is projected to double by 2030. And the past few decades have witnessed alarming increases in obesity and diabetes among the young.[1] Disability rates for the young have risen within all demographic and economic groups. The volume and intensity of health services are also rising rapidly.[2] All of these trends could significantly increase health care spending.[3]

This paper considers how new medical advances will affect health and health care delivery for the elderly. The type of innovation is important, and we consider several. Those that prevent disease — heart disease, diabetes, cancer and Alzheimer's are potentially the most promising — could protect large portions of the population and forestall expensive complications. Better treatments for existing disease might also be developed drawing on advances in gene therapy and bioengineering. But medical technology alone will not determine future outcomes; demographics and health trends also play a key role. So we also consider the implications for spending as successive cohorts age into Medicare. Next we describe the model we use to simulate future health and spending.

## MODEL OF ELDERLY HEALTH AND SPENDING

We developed a demographic and economic model to predict costs and health status for the elderly. The future elderly model (FEM) is a microsimulation that tracks elderly, Medicare-eligible individuals over time to project their health conditions, their functional status, and ultimately their Medicare and total health care expenditures. Much more detail is provided in an online technical appendix; below we summarize the salient details.

The FEM begins with a representative sample of approximately 100,000 aged Medicare beneficiaries from the 1992–1999 Medicare Current Beneficiary Survey (MCBS), as shown in Exhibit 1.[4] Starting in 2000, we predict health care spending for everyone in this cohort. These predictions come from pooled weighted least squares regressions of total health care spending on risk factors, self-reported conditions, functional status, and interactions of conditions and functional status.

We age our cohort by simulating health and functional outcomes in the subsequent year. This process requires knowledge of the underlying risk of changing health. We use the MCBS to estimate the one-year probabilities (hazards) of dying, developing a new health condition, or entering a new functional state as shown in Exhibit 2. Each hazard depended on risk factors, other health conditions and functional status where clinically warranted, and age. We treated all health conditions as "absorbing" — i.e., once people got an illness, they had it forever and therefore could not get it again — and modeled transitions into these conditions. This assumption was consistent with the way the data were obtained ("Has a doctor ever told you…") and with the course of most chronic diseases. Based on these hazard models, we then predicted each person's probability of dying, getting a new disease, or entering a new functional state using Monte Carlo techniques.

As our initial sample ages, it becomes less representative of the Medicare population. We annually replenish our sample through 2030 with a new cohort of 65-year-olds using data on the health of younger cohorts from the 1982 to 1996 National Health Interview Surveys to predict the health of new Medicare entrants. For example, the health of 65-year olds in 2026 will depend on the health of 35-year olds in 1996, appropriately trended. We then used this model to simulate the consequences of recent health trends.

## CONSEQUENCES OF RECENT HEALTH TRENDS

The health of the elderly has been improving in important ways since the early 1980s.[5] However, the rising prevalence of diseases like obesity and diabetes among the young and increases in disability suggest that future cohorts entering into Medicare may be less healthy.[1,6] The net effect of these trends is unclear. Improvements in health will allow the elderly to live longer and accrue more expenses and, as it is sometimes argued, ultimately incur more health care costs. The issue is further complicated because the effects depend in large measure on the mix of disease and disability, since not all conditions are equally expensive to treat over a lifetime.

We used our model to untangle these effects in three scenarios of the health of future entrants into Medicare. The first scenario, which is our preferred estimate, forecasts the constellation of disease taking into account all the information at our disposal, especially the health of the younger cohorts observed in the National Health Interview Study (Scenario A).[7] The second assumes that the entering cohorts will have a constellation of disease and disability similar to the healthy cohorts observed in the 1990's (Scenario B). This scenario ignores what we know about the disease and disability in younger populations. A final scenario assumes continued improvement in preventing disability among the entire elderly population and the entering cohort (Scenario C).[8]

Exhibit 3 summarizes the differences between these scenarios using any limitations in activities of daily living (ADL). Such limitations are important markers for both health care expenditures, the likelihood of entering a nursing home, and mortality. Under our preferred scenario (A), disability rates rise gradually until about 2012, fall gradually after that point, and rise again near the end. By 2030, 27.3% of the elderly will be disabled. If one (naively) assumes that the entering cohort to Medicare always resembles recent entrants (B), then

disability follows a similar pattern but ends up at 25.9% in 2030. This finding tells us that it is the demographic profile of the population — in particular the baby boom — that is driving disability more than the age profile of disease. Under the strong assumption of continual improvement in disability among all elderly (C), disability rates start to fall in 2006 and will be lower than the baseline by 5.1 percentage points in 2030.

Lower disability rates should translate into lower health care costs, as shown in Exhibit 4. The top panel shows spending on a per-capita basis. Under the preferred scenario (A), spending will be $8,759 per beneficiary in 2030 (measured in 1999 dollars). Under the most favorable assumptions (C), spending will be 8% lower by 2030 ($8,032 per beneficiary). However, any improvement in disability will also lead to mortality improvements and hence a larger elderly population. The bottom panel shows the impact on total spending by the elderly. There is little difference between Scenarios A and B; by 2030 spending under Scenario B is only $11.5 billion less per year, or 2%. So while the increasing burden of disease among the young may be a public health problem, it is not a trend that is likely to consequentially affect Medicare. Even in the best case, the potential savings are modest. By 2030, total spending would be $583 billion in Scenario C, compared with $621 billion for Scenario A, for a savings of 6%. The savings are lower for total spending (6%) than for per beneficiary spending (8%) because the attendant mortality improvement would result in approximately 1.7 million more elderly by 2030. Thus, much as Lubitz et al. (2003) found, cumulative Medicare spending is largely invariant to beneficiaries' health status when they enter Medicare because healthier individuals live longer.[3]

## CONSEQUENCES OF KEY MEDICAL TECHNOLOGIES

The previous scenarios assume no medical innovations of consequence; medicine continues to be practiced as it has been between 1992 through 2000 — the years spanned by our Medicare data. Total spending rises only because of demographic forces and because of underlying changes in the health of the population. This raises the question: what impact would new medical technologies have on these trends? [9]

To identify the technologies, we conducted systematic literature searches and then elicited consensus from several panels of distinguished experts. This process identified 34 technologies most likely to affect the health of the future elderly.[10] These innovations are classified into three clinical domains: cardiovascular disease, neurological disorders, and cancer and the biology of aging. For this analysis, we chose 10 of the technologies most likely to be widely adopted — three addressing cardiovascular disease, three addressing cancer; two addressing neurological disease; one addressing diabetes; and one related to general aging. A more detailed technical report describes how these technologies were selected and summarizes the evidence on efficacy driving the assumptions below.[10]

### 1. Intraventricular cardioverter defibrillators (ICD).

These devices can be implanted in the heart to continuously monitor the heart rhythm and apply a therapeutic shock when life-threatening arrhythmias are detected. This simulation greatly expands this technology to primary prevention: 50% of patients with either heart failure or a myocardial infarction would receive a surgical implantation at a one-time cost of

$37,500 (1999 dollars). We assumed no annual maintenance costs; this generous assumption is partially offset by the not allowing the cost of implants to decline over time, as one might expect with a mature technology. Patients with an ICD are assumed to have a 10% lower mortality rate.

2. **Left ventricular assist devices (LVAD).**

These devices, similar to "artificial hearts," are implanted into the chest to aid the left ventricle of the heart in pumping blood. This is a technology traditionally used as a bridge to heart transplantation; we model improvements to allow permanent implantation. About 10% of patients with heart failure would receive an implant at a cost of $120,000 and with subsequent mortality improvement of 15%. As with ICDs, we assume no maintenance costs as a partial offset to no decline in the device cost over time.

3. **Pacemakers to control atrial fibrillation.**

Atrial fibrillation is a disturbance of the heart rhythm that is common in older persons and contributes to both heart failure and stroke. Our panel considered several possible breakthroughs for improved control: new generations of pacemakers or defibrillators, use of a catheter to interrupt the pathways by which disordered electrical currents are maintained, and new drugs. Drugs were considered unlikely candidates to dramatically improve outcomes for this condition. Consequently, we consider the adoption of pacemakers to treat this condition. All patients with chronic or paroxysmal atrial fibrillation would receive a pacemaker at a cost of $30,000. The risk of stroke is reduced by 50%.

4. **Telomerase inhibitors.**

Telomerase inhibitors are molecules that prevent the expression of telomerase, an enzyme that allows cancer cells to replicate without limit. This treatment would target cancer patients with solid tumors. Our expert panels predicted that telomerase inhibitors could treat 50% of patients with local disease and 10% of those with disseminated disease (Exhibit 5). Using information on the types of cancer and the rate of metastasis, we assumed approximately 25% of all cancer patients would be treated. The cost of this treatment would be similar to an antiretroviral HIV drug — $177 per month and would be taken for the rest of one's life. Half of patients would be cured and the other half would have the effects of cancer mitigated, with the one-year probability of disability, nursing home entry, and mortality reduced by 25%.

5. **Cancer vaccines.**

Attempts to stimulate the body's immune system to fight cancer cells (analogous to vaccines to prevent viral disease) have been ongoing for more than 20 years. Active, non-specific immune stimulants successfully treated bladder cancer, and show promise for melanoma and renal cell carcinoma. Many vaccines directed against a tumor-associated antigen — and to which the host will respond — are in clinical trials. For this simulation, we used the same assumptions regarding cancer types and prevalence as in the telomerase inhibitor simulation. Treatment rates vary by the type of cancer and whether it has metastasized, as shown in Exhibit 5. Half of patients with local disease get treatment (21% of all cancer patients);

100% of patients with disseminated disease get treatment (41% percent of cancer patients) and 100% of patients with other cancers (18% of cancer patients). Because it is a vaccine, we assumed patients would only need 3 doses at a cost of $195; this price is three times as much as a hepatitis vaccine. Melanoma and renal cell carcinoma cases are cured (2% of all cancer patients) and the other treated patients have a 25% improvement similar to the uncured patients on telomerase inhibitors.

### 6. Anti-angiogenesis.

These treatments use human anti-growth factors to inhibit the development of new blood vessels, a prerequisite for the grown of cancer masses beyond about 1 centimeter in size. Infusions (or injections under the skin) would be given as an adjuvant to existing therapy for 40% of patients with solid tumors, as shown in Exhibit 5. The therapy — similar to taking bevacizumab for colorectal cancer — would cost $4,800 per month. We assume patients get the treatment for one year initially. At that time, 30% of patients are determined to be responsive and continue to receive the treatment for four more years. Therapy is assumed to be perfectly effective for these patients; that is, it shrinks the tumor to such a small size that the patient is effectively cured. The remaining 70% are non-responsive and go off the treatment.

### 7. Treatment of acute stroke.

It may be possible to limit the disability following acute stroke by decreasing the amount of programmed cell death that occurs in conjunction with ischemic cell death. This scenario assumes that the development of a neuroprotective drug would reduce the effect of stroke on disability by 50% and everyone with acute stroke would be eligible. The total cost of the medication would be $3,500 per year for those who are treated.

### 8. Prevention of Alzheimer’s.

Much effort has already been expended to find compounds that might delay the onset of Alzheimer’s disease. In our model, each person has a predicted rate of onset for Alzheimer’s disease that depends on age, gender, race, and education. This rate is used to simulate an age of onset for Alzheimer’s (if any). For this scenario, we added three years to the age of onset based on the consensus of our panel of neurological experts. So, for example, if a person developed Alzheimer’s at age 70 in our status quo simulation, then the disease appeared at age 73 (assuming he survived that long). This delay has the effect of reducing the prevalence of Alzheimer’s by about one-third. The cost is similar to a statin at $60 per month, and all elderly without Alzheimer’s disease take the drug.

### 9. Prevention of diabetes.

30% of the obese elderly (defined as BMI>30) are assumed to be treated by insulin sensitization drugs, which would reduce the hazard of diabetes by 50% over 15 years. Similar to rosiglitazone, the drug would cost about $108 per month and patients must continue to take the medicine until they die, regardless of the effects.

### 10. Compound that extends life span.

Restricting the caloric intake of mice and rats by 30 percent results in an approximate 25 percent extension in life expectancy. The mechanism underlying this effect is unknown. This technology considers a mythical compound that can reproduce this effect in humans. Only the incoming 65 years old cohorts are eligible and it is assumed that they have been taking the drug for 30 years with an annual cost of $365. Mortality is reduced in such a way that life expectancy is increased by approximately 10 years. We consider two scenarios: the first, consistent with biological evidence, assumes these years of life are healthy years, thereby compressing morbidity towards the end of the life-cycle. The second unhealthy scenario assumes the additional years of life are added at the end of life-cycle, with a concomitant increase in disease and disability.[11]

Exhibit 6 summarizes the impact of these technologies, assuming full adoption by 2002. The choice of a common adoption year is done to facilitate comparison between the technologies and to allow us to look out almost 30 years. Several striking patterns emerge from the table. Some technologies, when fully adopted, are forecasted to be extremely expensive. For example, the elderly could be spending $26 billion on ICDs by 2015 and - once one accounts for the attendant morbidity and mortality - the devices would increase overall elderly health care spending by 7%.

The ICD simulation is particularly germane in light of recent Medicare policy changes. As Hlatky et al (2005) note in their excellent discussion of ICDs, the devices are very effective for secondary prevention of sudden cardiac death. As a result, Medicare has covered ICDs for patients with a history of life-threatening arrhythmias (ventricular fibrillation) since 1986 and for less-severe arrhythmias (ventricular tachycardia) since 1999. The cost-effectiveness for such secondary prevention is around $54,000.[12]

More controversial is the impact of ICDs for primary prevention. Medicare already covers prophylactic use in patients at high risk of sudden death due to ischemic cardiomyopathy. But it is the most recent coverage decision that will greatly expand use to patients with heart failure or poor function in their left ventricle. Our simulation goes further and assumes half of elderly patients with new cases of heart failure or a heart attack will receive ICDs. Under these circumstances, there would be approximately 374,000 procedures performed annually in 2015 and 550,000 in 2030 at a total treatment cost of $14 billion and $21 billion, respectively. The cost for each additional life year is approximately $100,000.

Some technologies are not expensive by themselves (such as cancer vaccines), but add substantially to health care expenditures because of their efficacy. As people live longer, they incur more costs. Overall though, cancer vaccines are promising because of the substantial potential gains in life. Treatment of stroke with neuroprotective drugs would add $3-$4 billion annually (0.4% of total spending) once one accounts for mortality and morbidity changes. The cost per additional life-year is $22,000. Once one accounts for the potentially large morbidity effects — including reductions in nursing home entry — such technologies should be very cost-effective.

Other technologies achieve health improvements at a very high price. These include anti-angiogenesis, pacemakers for atrial fibrillation, and left ventricular assist devices. All of these are very expensive in relation to the health benefits they are known to produce. Our findings for anti-angiogenensis are consistent with recent experience with bevacizumab (trade name Avastin), an anti-angiogenesis drug used to treat patients with advanced colorectal cancer. This drug extends median survival by about 5 months at a treatment cost of $50,000 or more.[13] Our simulations show that if treatment is broadened, the cost per additional life year could go even higher. Without clear criteria for who will respond to anti-angiogenesis, and how long they will need to remain on these drugs, costs per additional life year are likely to be very high.

Telomerase inhibitors has the potential to save money to offset its treatment costs; treatment is forecasted to cost $6.4 billion by 2030 but total health care expenditures will rise very modestly (0.5%). These savings occur because people are dying of less expensive diseases. If the cost of the treatment could be reduced, it therefore could be very cost-effective. Attempts to prevent both diabetes and Alzheimer's disease are not forecast to be cost-effective, in part this is because they involve treatment of large fractions of the population, and the efficacy is limited. Better risk stratification in the future will allow for better targeting; however, these screening tests will also likely be very expensive initially. We also do not include any potential savings to families alleviated of the burden of illness, which can be very high with some diseases.

Finally, we simulated a compound to extend life span. Our expert panel suggested it would be a pill taken over a lifetime. The consequences are dramatic; under our healthy scenario it would increase health care spending by 14% in 2030, despite relatively little increase in morbidity and disability. The reason is simple: if such a pill had been available in 2002, the population of Medicare eligibles would be 13 million higher in 2030 than the current forecast (71 million). If such a pill could be developed with the efficacy profile we simulate, it would be worth $9,000 per additional life-year.

Under the less optimistic scenario that the pill keeps people alive but increases disease and disability, the consequences are enormous. Total health care spending in 2030 would be 70% higher than under the status quo, since there would be more elderly and people would incur disease and disability at older ages. Still, this treatment is relatively inexpensive – $30,000 per additional life-year. This scenario shows the inherent tension in medical improvements generally – we can keep people alive to incur more disease and disability, but the overall rate is one that many consider "worth it."

Simulations of this sort require certain caveats. First, we do not adjust our estimates – as many actuarial models do – to reflect historical trends in real health care costs. Including such projections would not change our conclusions about the relative impact of new innovations.[14] Furthermore, our goal is to isolate the effects of new technologies, whereas historical trends subsume some level of technological improvement. Thus, we would in some sense be "double counting" if we added a new technology on top of the trended projections.

More generally, changes in behavior are beyond the scope of our model, which is meant to highlight the effects of incremental improvements in medical technology. So, for example, our estimates of the effects of a drug that might improve longevity can be taken only as starting point for discussion. Such a technology is so transforming that it is well-beyond the capacity of such a model to deal with it. As life-expectancy moves beyond 100 years, people might take better care of themselves (or perhaps decide to “live-it-up”), work longer, and behave in fundamentally different ways. Society as a whole will be transformed. Our goal in presenting this scenario in particular is merely to demonstrate the technological risk embodied by current biomedical research—and consider its implications as best we can.

In addition, the ultimate effect of a technology depends on its timing and its price, both of which are difficult to forecast, are interrelated, and influence diffusion. But it is unclear how to forecast future prices in the context of our model. The panels recognized, but could not predict, that costs of a procedure will fall over time with higher rates of adoption. We assumed these technologies were similar to treatments they resemble or replace.

Finally, it should be noted that we focus on the elderly. Of course, access to technology will not be restricted to older Americans. Many of the new treatments will be expensive and hence will raise the cost of health insurance for the non-elderly, and fewer people will be able to afford comprehensive coverage. With fragmented health insurance markets and incomplete health insurance coverage, the fruits of medical progress will be distributed unevenly. Furthermore, the benefits that any socioeconomic group derives from innovations will depend on the prevalence of treatable disease in that group. If we design cures for the diseases of “rich people” — as cardiovascular disease once was — then gradients in health are likely to widen.

## CONCLUSION

A forecasting exercise is less important as a literal “reading of the future” than as an attempt to unpack the competing forces of the present day. Two issues are paramount in this discussion. First, the rising prevalence of chronic disease among the near elderly will continue to drive gradual increases in morbidity among the elderly with only a modest increase in health expenditures. At the same time, advances in bioengineering, genetics, the life sciences, and clinical medicine may lead to rapid improvements in medical care. The most important technologies on the horizon, however, will resemble those from the past — they result in modest improvements in health that are often, but not always, worth the cost. Our simulations indicate that society faces the greatest spending risk from technological rather than health status changes.

These two trends are of course fundamentally related: technological improvements and increases in chronic diseases such as cardiovascular disease and diabetes are both symptoms of widespread economic progress. These improvements are not accidental; they are the results of the greatest investment in biomedical research in history. Although medical research has been successful in combating many diseases, the development of a technological fix that makes us all behave in healthy ways has not been forthcoming.

## Acknowledgments

This work was funded by the Center for Medicare and Medicaid Services (Contract No. 500–95-0056) and the National Institute on Aging through its support of the RAND Roybal Center for Health Policy Simulation (P30AG024968), the RAND Center for the Study of Aging, National Institute of Aging (AG-10415) and the Stanford Center for Demography and Economics of Health and Aging (AG17253).

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4. The MCBS sample consists of aged and disabled beneficiaries enrolled in Medicare. It attempts to interview each person twelve times over three years, regardless of whether he resides in the community or in an institution. Each fall a new panel is introduced with a target sample size of 12,000 respondents, and each summer a panel is retired.
5. Crimmins EM, Saito Y and Reynolds SL, “Further Evidence on Recent Trends in the Prevalence and Incidence of Disability among Older Americans from Two Sources: The Lsoa and the Nhis,” The Journals of Gerontology: Series B, Psychological Sciences 52, no. 2 (1997): S59–71;Manton KG, Corder L and Stallard E, “Chronic Disability Trends in Elderly United States Populations: 1982–1994,” Proceedings of the National Academy of Sciences of the United States of America 94, no. 6 (1997): 2593–2598; [PubMed: 9122240] Schoeni RF, Freedman VA and Wallace RB, “Persistent, Consistent, Widespread, and Robust? Another Look at Recent Trends in Old-Age Disability,” The Journals of Gerontology: Series B, Psychological Sciences 56, no. 4 (2001): S206–218.
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7. As a hypothetical example, if we find in the National Health Interview Survey that 50-year olds in 2004 have a prevalence of diabetes of 10%, but 45-year olds have a prevalence of 12%, then one would expect that when these cohorts enter Medicare in 2019 and 2024, respectively, that the younger cohort would have a greater prevalence of diabetes by at least 2%. The actual difference is greater than 2% because we allow for the fact that there is an age-specific trend in diabetes. More details can be found in the companion technical report.
8. For this simulation, the one-year probabilities of one or two ADL limitations and 3 or more disabilities were cumulative reduced by 1% per annum. In addition, we assumed the entering cohort to Medicare would experience a decline in disabilities of 0.56% per year, as Manton and Gu find using the National Long Term Care Survey. Otherwise, the forecast of disease and disability for the incoming cohort is based on the National Health Interview Survey.
9. Our baseline differs from the baseline produced by official estimates of future Medicare spending. Their baseline forecasts include a rate of technological advancement through improved mortality and higher spending. Such an assumption is inappropriate here since we want to isolate the consequences of a particular technology, and such technologies are implicitly embedded in the actuaries’ baseline forecast. Thus, our baseline is a standard of medicine practiced in the 1990’s, whereas their baseline is their prediction of how medicine will be practiced in future years.
10. These technologies – and the process used to identify them – are described in more detail *in* (Goldman DP, et al., Health Status and Medical Treatment of the Future Elderly: Final Report, Pub. no. TR-169-CMS (Santa Monica, CA: RAND Corporation, 2004))
11. We implemented the unhealthy scenario by reducing the mortality hazard for treated individuals by 80%; this corresponds to an increase in life expectancy at age 65 from 19 to 29 years. The healthy scenario reduced all hazards (mortality, disease, and functional limitations) by 63%, corresponding to a similar change in life expectancy.

12. Hlatky MA, Sanders GD and Owens DK, “Evidence-Based Medicine and Policy: The Case of the Implantable Cardioverter Defibrillator,” Health Affairs (Millwood) 24, no. 1 (2005): 42–51.
13. Hurwitz H, et al., “Bevacizumab Plus Irinotecan, Fluorouracil, and Leucovorin for Metastatic Colorectal Cancer,” New England Journal of Medicine 350, no. 23 (2004): 2335–2342. [PubMed: 15175435]
14. Real health care spending, after adjusting for demographic changes, grew by about 4%. Cost-effectiveness studies often discount future spending by 3%. If we included both, the resulting estimates would not be appreciably different.

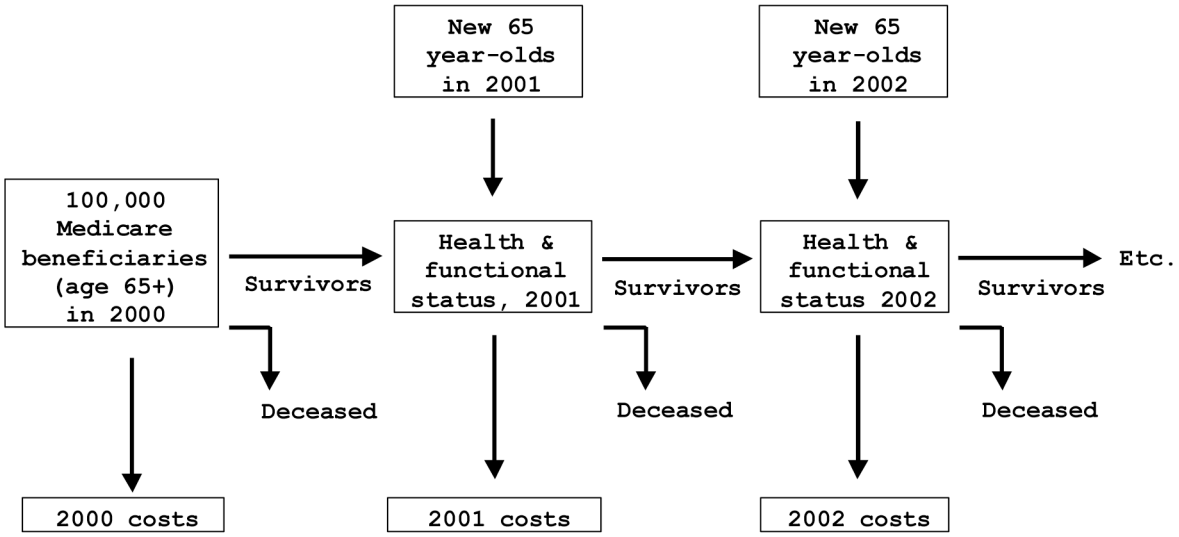


**Exhibit 1.**
Overview of the Simulation Model

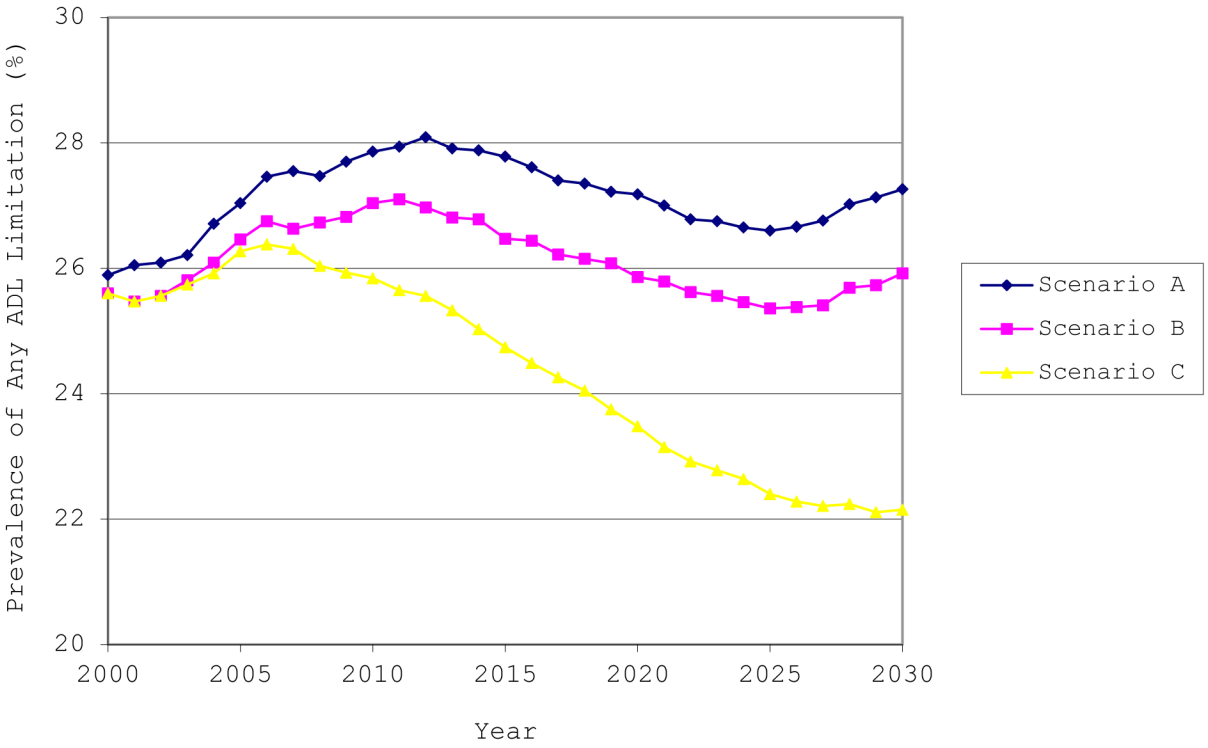


**Exhibit 3. Disability Among the Elderly Under Three Scenarios, 2005–2030**

Notes for Exhibits 3 and 4: The Figures show forecasts of disability prevalence and health care costs under three scenarios based on data from the Medicare Current Beneficiary Survey and the National Health Interview Study. Scenario A, our preferred scenario, incorporates health status information for younger cohorts, including information on prevalence of disability and major chronic conditions. Scenario B ignores this information and assumes that entrants to Medicare resemble recent entrants. Scenario C assumes that disability is falling among all the elderly based on trends from the 1990's

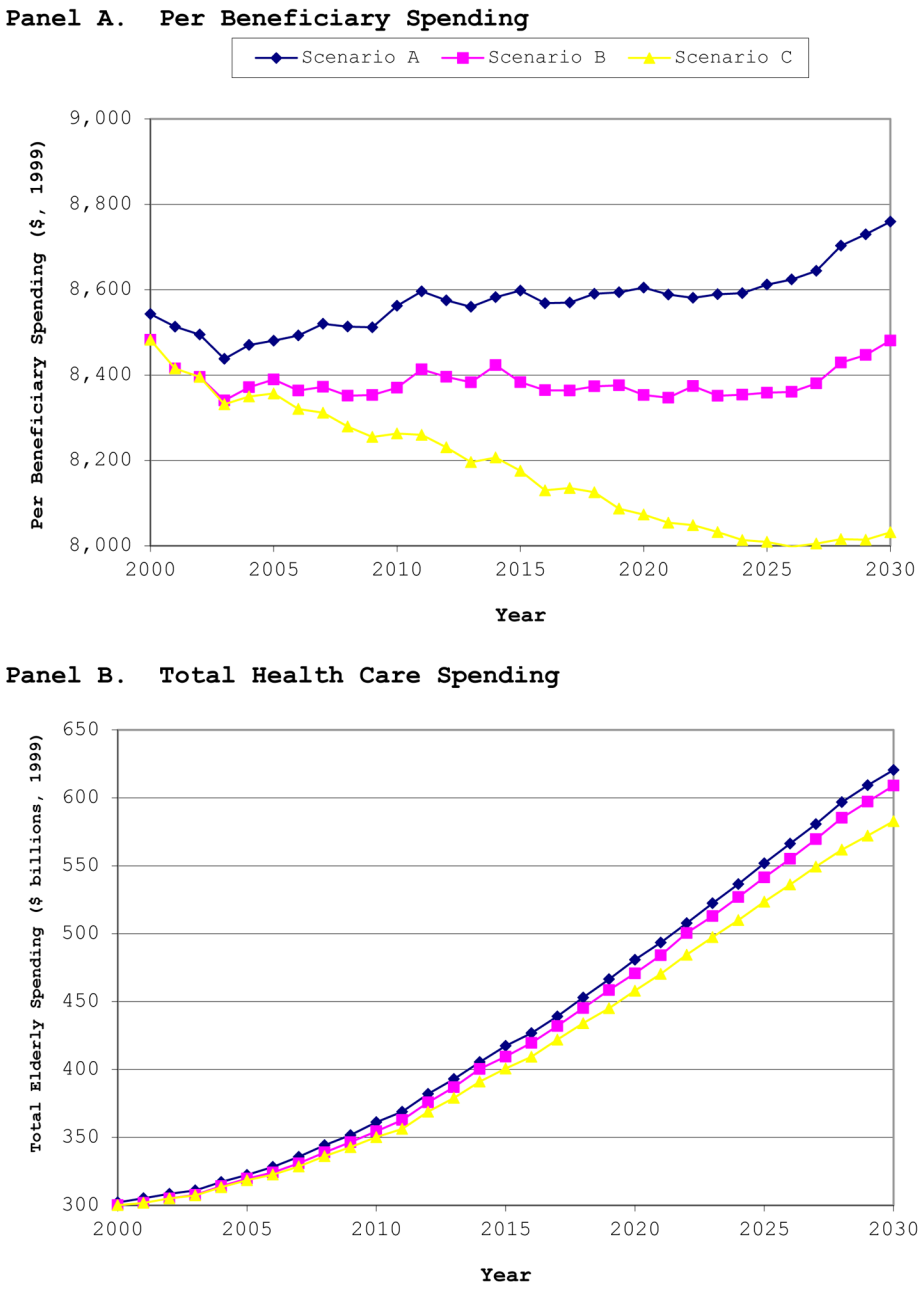


**Exhibit 4.**
Health Care Spending by the Elderly, 2004 to 2030

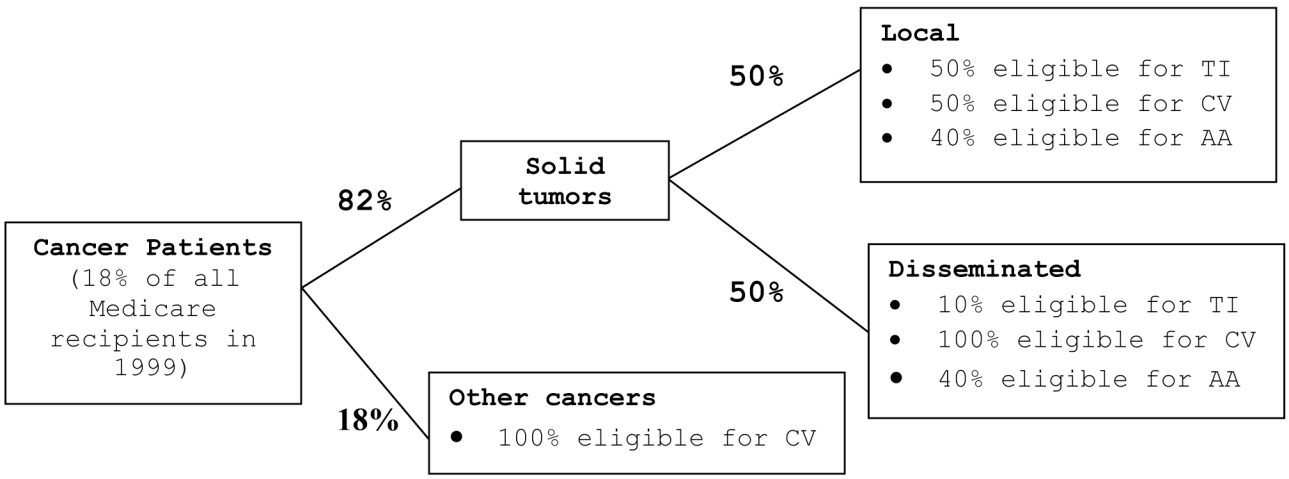


**Exhibit 5. Cancer Classification and Eligibility for Breakthrough Treatment**

Notes: Figure shows the prevalence of various forms of cancer in the elderly Medicare population. Eligibility for three cancer treatments are shown: TI=telomerase inhibitors; CV=cancer vaccines; and AA=anti-angiogenesis.

**Exhibit 2.**

Health Conditions, Functional States, and Risk Factors Included in the Simulation Model

| **Conditions** *(1)* | **Functional state** *(2)* | **Risk Factors** *(3)* |
|---|---|---|
| Hypertension | 1+ ADLs | Obese |
| Diabetes | 3+ ADLs | Underweight |
| Heart disease | Nursing home | Ever smoked |
| Lung disease | Dead | Age |
| Alzheimer's | | Gender |
| Arthritis | | Education |
| Cancer | | Race |
| Stroke | | Ethnicity |

*(1)* Based on self-report; conditions are permanent ("ever had")

*(2)* Mutually exclusive; "ADL" refers to difficulty performing or inability to perform one of six activities: bathing or showering, dressing, eating, getting in or out of bed or chairs, walking, using the toilet.

*(3)* Do not vary over time

**Exhibit 6.**

The Impact of Selected Medical Technologies on Expenditures and Life Years, 2002-2030

| Technology | Annual Treatment Cost ($ billions) | | Increase in health care spending over status quo (%) | | Cost per additional life-year |
|---|---|---|---|---|---|
| | 2015 | 2030 | 2015 | 2030 | |
| Anti-aging compound (healthy) | 48.6 | 72.8 | 8.7 | 13.8 | 8,790 |
| Cancer vaccines | 0.5 | 0.8 | 0.1 | 0.4 | 18,236 |
| Treatment of acute stroke | 3.1 | 4.4 | 0.4 | 0.4 | 21,905 |
| Anti-aging compound (unhealthy) | 48.8 | 73.3 | 22.7 | 70.4 | 29,785 |
| Telomerase inhibitors | 4.4 | 6.4 | 0.2 | 0.5 | 61,884 |
| Alzheimer's prevention | 33.6 | 49.1 | 7.4 | 8.0 | 80,334 |
| Intraventricular cardiodefibrillators | 14.0 | 20.7 | 3.6 | 3.7 | 103,095 |
| Diabetes prevention | 13.7 | 20.6 | 2.6 | 3.2 | 147,199 |
| Antiangiogenesis | 38.8 | 51.9 | 8.8 | 8.0 | 498,809 |
| Left ventricular assist devices | 10.2 | 14.2 | 2.1 | 2.3 | 511,962 |
| Pacemaker for atrial fibrillation | 10.4 | 13.6 | 2.2 | 2.3 | 1,403,740 |

Notes: All spending is in constant (1999) dollars. The exhibit shows the treatment costs, additional health care expenditures, and cost per additional life-year associated with 10 promising medical innovations. Treatment costs refer to the costs of providing the listed breakthrough and are based on comparisons with existing technologies as identified by expert panels. The additional health care expenditures differ from treatment costs because the breakthroughs can lead to changes in disability, morbidity and mortality, all of which are accounted for in the simulation model. Costs per additional life year do not include improvements in morbidity and disability during a lifetime and hence should be thought of as upper bounds on a cost-effectiveness ratio. The simulations are based on data from the Medicare Current Beneficiary Survey and the National Health Interview Study.