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IDENTIFYING POTENTIAL HEALTH CARE INNOVATIONS FOR THE FUTURE ELDERLY

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Abstract

We used a method that combined literature review and expert judgment to assess potential medical innovations for older adults. We evaluated innovations in four domains: cardiovascular disease, cancer, the biology of aging, and neurologic disease. The innovations can be categorized by common themes: improved disease prevention, better detection of subclinical or early clinical disease, and treatments for established disease. We report the likelihood, potential impact, and potential cost implications for thirty-four innovations, and we revisit this forecast five years later. Many of the innovations have the potential to greatly affect the costs and outcomes of health care.

The unprecedented progress in biomedical as well as clinical and health services research during the final quarter of the twentieth century will continue to drive a revolution in medicine that is expected to last for at least the next quarter-century. Every aspect of the prevention, diagnosis, treatment, and monitoring of disease processes has been affected by this revolution.

Behind this wave of advancement is a convergence of progress in many of the traditional life science fields, including anatomy, biochemistry, immunology, microbiology, physiology, genetics, pharmacology, health services, and clinical medicine, together with contributions from chemistry, physics, mathematics, computer science, and engineering. Scientists from widely divergent disciplines are now crossing over to other fields or collaborating to form multidisciplinary teams that are tackling problems of such magnitude that they could not have been approached within any one field.

Keeping up with the rapidity of change is difficult enough. Predicting its possible course may be foolhardy. Nonetheless, because new technologies of all types are a driving force behind changes in health-related outcomes and costs of care, we accepted the dual challenge of developing a method to predict the impact of new technologies on health care for the elderly in the next ten and

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twenty years and then applying this method to estimate the impact of these innovations. Used appropriately, the results of our analyses might help us make more rational health policies as we cope with questions ranging from, “Will these new innovations improve important outcomes?” to, “Will we be able to afford them?” to, “What personnel will be needed to provide them?”

In this paper we outline the systematic method we developed for identifying expert opinion to synthesize the range of possible scenarios. The result is a list of innovations with the probability of their entrance into clinical practice over the next ten to twenty years. The results should focus attention on the key innovations that have the most potential to change the way we prevent, diagnose, and treat disease.

STUDY METHODS

Previous attempts to assess potential future technologies have relied on at most a few experts, whose opinions were gathered and assessed informally. We developed a quantitative method that combines lessons learned from the field of evidence-based medicine (EBM) on conducting literature reviews, the use of “horizon scanning searches,” and focused expert judgment.[1]

In brief, we began by convening a panel of six leading geriatricians and asking them to identify clinical domains in which potential innovations would have the largest impact in terms of costs and health status. This group selected cardiovascular disease, cancer and the biology of aging, and neurologic disease as the most important clinical domains. Groups of technical experts were then selected for each of the three topic areas. [2] The technical experts were surveyed individually for their opinions regarding the leading potential medical innovations in each area. In making these decisions, they were asked to consider the likelihood that an innovation could occur, its potential impact, and the potential cost implications. For each of the selected potential medical innovations in these domains, we next conducted a comprehensive literature search. [3]

Each of the three expert panels were given the results of this literature search and met for one day to discuss the potential innovations. [4] We used a combination of (1) nominal group process to list and define potential innovations for further discussion, (2) informal group process to discuss the evidence and opinion regarding each topic, and (3) formal voting to develop specific estimates for the following four subjects: the target population to whom the innovation would apply; the likelihood of the innovation’s occurring in the next ten years and the next twenty years; the innovation’s expected impact on morbidity and mortality; and the innovation’s expected cost.

RESULTS

EXPERT PANEL MEETINGS.

Based on the results of the nominal group process, the original list of potential innovations was modified and expanded in more detail. Exhibits 1 – 3 list the thirty-four potential innovations for which quantitative estimates were developed.

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Exhibit 1.

Summary Results for Potential Innovations: Cardiovascular Diseases

Innovation	Likelihood of occurrence at 20 years	Brief Summary of Impact
Improved disease prevention	40%	90% reduction in cardiovascular disease.
Noninvasive diagnostic imaging to improve risk stratification		Better identification of high risk patients, leading to effective risk reduction strategies.
• General population >45	15%	
• Subclinical disease	75%	
• Clinical disease	50%	
Magnetic resonance angiography (as a replacement for coronary catheterization)	100%	Replacement for conventional coronary angiography, likely to increase the number of persons undergoing the procedure.
Implantable cardioverter defibrillators for clinical disease	30–40%	Life expectancy for people with heart failure gets shifted by 6–10 months, 20% now die of some other cause.
Left ventricular assist devices (LVAD)	50%	General increase in function for persons with functional limitations, 50% decrease in heart failure-related hospitalizations, 20% of patients will have improved 1 year mortality.
Xenotransplants	1–3%	Possibly similar to the benefit from human heart transplants, but several experts thought the impact would be lower as the population affected is likely to be different.
Therapeutic angiogenesis		Little effect on mortality, decreased number of revascularization procedures by 20–30%.
• Clinical disease: augmentation for revascularization	Currently used	
• Clinical disease: replacement for revascularization	10%	
Transmyocardial revascularization	0–5%	Little effect on mortality, decreased number of revascularization procedures by 20–30%.
Pacemaker/defibrillators to control atrial fibrillation	50%	Decreased stroke by 50% of the attributable fraction due to atrial fibrillation.
Catheter-based ablation techniques to control atrial fibrillation	20%	Decreased stroke by 50% of the attributable fraction due to atrial fibrillation.

SOURCE: Adapted from D.P. Goldman et al., *Health Status and Medical Treatment of the Future Elderly: Final Report,* Pub. no. TR-169-CMS (Santa Monica, Calif.: RAND, 2004), Table 3.1.

Exhibit 2.

Summary Results for Potential Innovations: Cancer and the Biology of Aging

Innovation	Likelihood of occurrence at 20 years*	Brief Summary of Impact
Telomerase inhibitors	100%	Mortality: 50% will be cured; 50% will have a 25% prolongation of life.
Cancer vaccines	10–20%	Melanoma/renal cell carcinoma could be cured. All other cancers could have a 25% boost in survival.
Selective estrogen receptor modulators	90%	Breast cancer decrease of approximately 30%, decreased osteoporosis (increase bone density in spine of osteoporotic women by 2%).

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Innovation	Likelihood of occurrence at 20 years*	Brief Summary of Impact
Antiangiogenesis	70–100%	Disease arrest for metastatic disease in 10–50% of solid tumors.
Diabetes prevention via drugs that enhance insulin sensitivity	65%	50% prevention in Type II diabetes over more than 10–15 years.
Compounds that extend life span	0–50%	10–20 years of extra life of an equivalency between 20–50 years of age.
Compounds that improve cognition	20%	Decrease in traffic accidents and pedestrian accidents due to improved reflex ability, increased period of participation in the work force.

SOURCE: Adapted from D.P. Goldman et al., *Health Status and Medical Treatment of the Future Elderly: Final Report,* Pub. no. TR-169-CMS (Santa Monica, Calif.: RAND, 2004), Table 3.2.

Exhibit 3.

Summary Results for Potential Innovations: Neurologic Diseases

Innovation	Likelihood of occurrence at 20 years*	Brief Summary of Impact
Improved identification of persons at risk for Alzheimer's disease	30%	No direct impact on mortality or morbidity, but it will identify people at higher risk for guided treatment.
Primary prevention of Alzheimer's disease Using therapies based on the amyloid hypothesis	40%	Delay of onset by a median 5 years (range 3–10 years), slow progression by a mild to moderate amount.
Primary prevention of Alzheimer's disease using existing or other new drugs	40%	Delay of onset by 2–5 years, minor impact on progression.
Treatment of established Alzheimer's disease by vaccine, secretase inhibitor, antioxidants, anti-inflammatories, or selective estrogen receptor modulators	30%	Decrease in rate of progression that is mild to moderate.
Treatment of established Alzheimer's disease by cognition enhancers	40%	Shift back in time by 6 months to 2 years but does not modify the disease.
Prevention and treatment of Parkinson's disease by profiling genetic predisposition for susceptibility to environmental toxins	10%	Eliminate disease in 15% of existing cases, delay onset in 15–20% of cases.
Treatment of Parkinson's disease therapies by neurotransplantation	25%	Shift back in time by 2 to 5 years but does not modify disease.
Treatment of acute stroke by drugs that minimize cell death	60%	Decrease in disability due to stroke of median 30% (range 25–50%).
Treatment of acute stroke by stem cell transplant	20%	Decrease in disability due to stroke of 25%.
Improved treatment of depression using new or existing drugs	70%	70% improvement in symptoms (e.g. 35% improvement over placebo).

SOURCE: Adapted from D.P. Goldman et al., *Health Status and Medical Treatment of the Future Elderly: Final Report,* Pub. no. TR-169-CMS (Santa Monica, Calif.: RAND, 2004), Table 3.3.

These innovations could be categorized according to three common themes: improved disease prevention, better detection or risk stratification of people with subclinical or early clinical disease, and treatments for established disease. Improved prevention was the subject of innovations in all three of the expert panels. Nearly all of these innovations had relatively low per person costs. However, because they would need to be applied to very large

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populations, their cumulative costs might be high. Counterbalancing these costs would be potential decreases in the direct and indirect costs of care related to the prevented conditions.

Breakthroughs leading to better detection or risk stratification of people with subclinical or early clinical disease were identified by the cardiovascular and neurological panels. The concept behind this category of innovations is that better detection of subclinical or early clinical disease will allow for better targeting of effective therapies to ameliorate the progression of morbidity and mortality associated with the diseases.

Breakthroughs for patients with established disease were identified by all three panels and can be categorized into four types: new pharmaceuticals, new advances in biomedical engineering, innovations that target specific genes or cells, and use of cell or organ transplantation.

We next discuss in more detail some selected innovations from each condition, chosen because of their likelihood of occurrence and their use in a paper by Dana Goldman and colleagues that models their potential health and economic effect. [5] The quantitative estimates for the innovations are presented elsewhere. [6]

POTENTIAL BREAKTHROUGHS IN CARDIOVASCULAR DISEASE.

Implantable cardioverter defibrillators (ICDs).—Sudden cardiac death due to ventricular arrhythmia is a leading cause of death. ICDs can be implanted in the heart to continuously monitor the heart rhythm and apply a therapeutic shock when life-threatening arrhythmias are detected. At the time of our expert panel meetings, this technology existed but was limited in use to a very select group of patients. Major clinical trials were ongoing but had not yet reported results. Our expert panel judged ICDs for broader patient populations to be 30 percent likely over the next ten to twenty years, in particular among patients with heart failure. The expected impact was to moderately prolong life in up to half of patients with heart failure and to potentially result in more patients with limitations in functioning, since they would no longer die of arrhythmia. The estimated cost was $35,000–$40,000 per case.

Left ventricular assist devices (LVADs).—LVADs are implanted into the chest to aid the left ventricle of the heart in pumping blood. This is a technology that exists as a bridge to transplant, but improvements in the devices would allow permanent implantation. Our expert panel judged that up to 10 percent of patients with heart failure could benefit from expanded use of these devices, with a likelihood of 10 percent at ten years and 50 percent at twenty years. The expected impact was improvement in mortality and functioning with a decrease in heart failure related hospitalization, at a cost of $120,000 per case.

Pacemakers to control atrial fibrillation.—Atrial fibrillation is a disturbance of the heart rhythm that is common in older people and contributes to both heart failure and stroke. Our panel considered several possible innovations for improved control: new generations of pacemakers or defibrillators, use of catheters to interrupt the pathways by which disordered electrical currents are maintained, and new drugs. Our expert panel judged that all people with chronic or paroxysmal atrial fibrillation would be eligible for this innovation, and the

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likelihood of this occurring was high: 50 percent at ten years. The expected impact was to decrease stroke by up to 50 percent, decrease the use of the blood thinner coumadin, and decrease atrial fibrillation–related hospitalizations. The cost was expected to be $20,000–$40,000 per year.

POTENTIAL BREAKTHROUGHS IN THE TREATMENT OF CANCER AND THE BIOLOGY OF AGING.

Anti-angiogenesis.—Anti-angiogenesis involves the use of human anti–vascular growth factors that inhibit the development of new blood vessels, a prerequisite for the growth of tumor masses larger than about one centimeter in diameter. Many successful studies have been conducted in animals, and anecdotal reports of success have been reported in humans. Phase III randomized trials are ongoing. [7] Results of one trial have recently led the U.S. Food and Drug Administration (FDA) to approve bevacizumab in patients with colorectal cancer. [8]

The expert panel considered anti-angiogenesis to be potentially useful for all patients with solid-tumor cancers (such as lung, breast, colon, prostate, and pancreas). The therapy could be given both for local disease (as an adjunct to resection) and as an adjunct to other therapies such as radiation therapy or conventional chemotherapy for metastatic disease. The panel predicted this innovation to be very likely, with a 70–100 percent likelihood of occurrence in the next ten years. By twenty years, the panel predicted, it would certainly be in routine use, unless clinical trials establish lack of effectiveness, in which case it would not be used at all. The impact was judged as possibly providing “disease arrest” for metastatic disease in 10–50 percent of patients. The cost was judged to be similar to treatments involving existing human growth hormones such as erythropoietin, which has an average wholesale price of $120 per 10,000 unit dose. The number and frequency of doses that would need to be given is unknown but could possibly be daily or weekly for a period of weeks to months.

Telomerase inhibitors.—Most cancer cells express telomerase, an enzyme that inhibits the shortening of DNA during cell division and hence enables an infinite number of cell divisions. Telomerase inhibitors are small molecules that act to stop the enzyme telomerase, rendering cancer cells again subject to a finite number of divisions and preventing cancer from spreading. There is substantial in vitro evidence of the successful effects of telomerase inhibitors, but clinical use has not been attempted. Our expert panel considered this innovation to be very likely: 50–60 percent at ten years and 100 percent at twenty years (if found to be effective). The expected impact was that half of patients with solid tumors (not leukemia or lymphoma) and no evidence of metastasis, and 10 percent of those with metastasis, would be eligible for the treatment, and half would be “cured.” The expected cost was similar to other molecules affecting replication, such as various HIV drugs.

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 twenty years. Active, nonspecific immune stimulants have been used to successfully treat bladder cancer and show promise for melanoma and renal cell carcinoma. [9] Many vaccines directed

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against a tumor-associated antigen—and to which the host will respond—are in clinical trials. Our expert panel thought that this innovation was moderately likely—10 percent at ten years, rising to 20 percent at twenty years. About half of patients with both solid tumors and hematologic cancers (leukemia, lymphoma) would be eligible; of these, patients with certain cancers (renal cell, melanoma) might be cured, while others could have a 25 percent boost in survival. Cost was estimated to be similar to the hepatitis vaccine.

Compound that extends life span.—It has been known for years that 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 topic considers a mythical compound that reproduces in humans the effect of caloric restriction in rodents. The experts on our panel had widely differing views of the likelihood of this innovation: 0–15 percent at ten years, rising to as high as 50 percent at twenty years. Everyone would take such a pill, for life. The expectation is that such a compound would provide an extra ten to twenty years of life of an equivalency to that between ages twenty and fifty today. The cost for such a pill would be about the same as for a nutritional supplement.

POTENTIAL BREAKTHROUGHS IN NEUROLOGICAL CONDITIONS.

Alzheimer's prevention.—Breakthroughs affecting Alzheimer's disease that were discussed include those that would improve identification of people at increased risk; primary prevention using compounds based on the amyloid hypothesis; primary prevention using existing or new drugs; treatment of established disease by vaccine, secretase inhibitors, antioxidants, anti-inflammatories, or selective estrogen receptor modifiers (SERMs); and treatment of established disease by cognition enhancers.

Interventions based on the amyloid hypothesis, such as a vaccine or secretase inhibitors, have been proposed for the primary prevention of Alzheimer's disease. At the time of this panel, successful studies of a vaccine in mice had just been reported. [10] Our expert panel considered that a successful innovation in this area would be useful for people currently known to be at high risk of developing Alzheimer's, those who would be identified to be at high risk by tools that are yet to be discovered, or those with early stages of the disease. The panel judged this innovation to be moderately likely, with a 20 percent likelihood of occurrence in the next ten years, rising to 40 percent at twenty years. The impact of this innovation was predicted to be a delay in the onset of symptoms of Alzheimer's disease by a median of five years and a slowing in the progression of symptoms by 20–50 percent. The cost for a vaccine was predicted to be about $1,000 per shot, with two to three shots required per person initially. The cost for a secretase inhibitor was predicted to vary between the cost of existing "statin" medications (at the low end of the estimate) and the cost of protease inhibitors (at the high end).

Treatment of acute stroke.—It could be possible to limit disability following acute stroke by decreasing the amount of programmed cell death that occurs in conjunction with ischemic cell death. Many molecules have in vitro evidence of a cytoprotective or neuroprotective effect with anoxia; animal trials have been disappointing to date. [11] The expert panel thought that this innovation was very likely: 40 percent at ten years, rising to 60

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percent at twenty years. All people with acute stroke could be eligible for such treatment. The expected impact was a 30 percent decrease in poststroke disability and a decrease in subsequent rehabilitation. The expected cost was $3,000–$4,000.

POTENTIAL INNOVATIONS IN DIABETES.

There is some evidence that a pill may one day help prevent the onset of Type II diabetes mellitus (data not shown). For example, in the Heart Outcomes Prevention Evaluation (HOPE) trial, an unanticipated result was a decrease in the incidence of diabetes in patients treated with angiotensin-convertin enzyme (ACE) inhibitors. [12] Insulin-sensitizing drugs are also in development. Our expert panel judged this innovation to be very likely, with a 50 percent chance at ten years, rising to 65 percent at twenty years. People at high risk of developing diabetes would be targeted for this intervention, and the expected impact would be 50 percent reduction in the five-year incidence of diabetes. The expected cost would be similar to current oral hypoglycemic agents.

DISCUSSION

We developed a method that combines literature review, horizon-scanning searches, and expert judgment to identify and estimate the impact of medical innovations that are likely to be implemented over the next ten to twenty years. This process yielded thirty-four potential innovations in three areas. In the five years since our panels met in 2000, some of these innovations have had good evidence supporting their effectiveness, including ICDs and anti-angiogenesis for cancer, both of which are now used routinely. [13] Others are still progressing in terms of basic and clinical research at about the rate the panel members expected, including therapeutic angiogenesis, transmyocardial revascularization, the genetic basis for prolonging life, telomerase inhibitors, and the effectiveness of cancer vaccines. [14] Still others are considered correct in principle, although the specific technology for the innovations may have changed. For example, rapid multidetector computed tomography (CT) scanning of the heart may now be closer to clinical use than magnetic resonance angiography as a replacement for coronary angiography, at least for screening purposes. [15] Similarly, in an informal reassessment, our experts were still enthusiastic that pharmaceutical compounds would be found that delay the onset of Type II diabetes. Some estimates of innovations probably “overshot the mark,” such as LVADs and xenotransplants, although research is still progressing. The impetus for pacemakers to help control atrial fibrillation has slowed somewhat since the recognition that patient outcomes were not adversely harmed with rate control compared to rhythm control, although new approaches are under development. [16] A few innovations have had setbacks, in particular neurotransplantation for Parkinson’s disease and the development of a vaccine for Alzheimer’s disease (although research in both areas is ongoing). [17] Lastly, our process did not anticipate some major innovations, including drug-eluting stents in the treatment of coronary artery disease, the potential for stem cells in myocardial disease, and the emergence of small molecules that can dramatically improve some hematopoeitic cancers, such as imatinab. [18]

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We realize that forecasting the future is a field dominated by fools, wizards, and science fiction writers. We also realize that any one of the methods we used could be criticized and that combining the methods might simply compound the error of any one method. Furthermore, our method cannot forecast innovations that occur when serendipity interacts with the prepared mind, such as the discovery of penicillin. Nonetheless, our method uses the best social science information and is much more rigorous than asking a single expert to provide an opinion.

Considering the limitations we identified, why are these results important? In the United States and the rest of the world, many of the benefits derived from health care and much of the driving force behind rising costs can be attributed to the use of technology. Therefore, by necessity, all of the estimates of future medical costs in the developed world require assumptions about new technology. These estimates are now based on simple actuarial extrapolations of data from past experience or on the opinions of a small number of experts. However, estimates that more accurately identify future technological innovations and incorporate them into actuarial decision models are likely to be more useful for decision makers in determining resource needs in the coming decades. We believe that our systematic approach represents an improvement over current methods, and we hope that we have stimulated the beginning of a new endeavor.

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NOTES

1. For more details, see Goldman DP et al., Health Status and Medical Treatment of the Future Elderly: Final Report, Pub. no. TR-169-CMS(Santa Monica, Calif : RAND, 2004).
2. Ibid., for names and affiliations of the expert panel members.
3. Ibid.
4. The literature searches identified a total of 12,136 titles in cardiovascular disease, 2,029 titles in cancer and in the biology of aging, and 6,751 titles in neurologic diseases. Of these, 108, 213, and 78 articles (respectively) were selected as relevant, critically reviewed, and summarized in tables and text for use during the expert panel meeting.
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