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Abstract

To identify successes in improving America’s health, we identified disease categories that appeared on vital statistics lists of leading causes of death in the US adult population in either 1950 or 2000, and that experienced at least a 50% reduction in age-adjusted death rates from their peak level to their lowest point between 1950 and 2000. Of the 9 cause-of-death categories that achieved this 50% reduction, literature review suggests that 7 clearly required diffusion of new innovations through both public health and medical care channels. Our nation’s health success stories are consistent with a triangulation model of innovation plus public health plus medical care, even when the 3 sectors have worked more in parallel than in partnership.

There has been much discussion of the relative importance of population-based risk factors versus individual medical care in determining the health outcomes of the US population.1,2 The sibling rivalry between public health and medicine (sometimes referred to as “sick-care” by public health professionals) has often suggested that successes in improving America’s health could be easily attributed to one or the other. Joint successes of their combined activity have not been clearly identified.

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Contributors

G. Rust originated the study and supervised all aspects of its implementation, including interpretation of the data and writing the article. D. Satcher and R. S. Levine assisted with framing the original study question for the article and provided guidance, feedback, and editing on the article throughout all stages. G. E. Fryer assisted with the design, data acquisition, interpretation of results, and writing of the article. D. S. Blumenthal assisted with interpretation of results in writing the article.

Human Participant Protection

No protocol approval was needed for this study, which was based entirely on public information from secondary data sets and published data available through the Internet.
The 20th century was characterized by a major transition in the causes of death, from mostly infectious diseases to more chronic, degenerative diseases. This “epidemiological transition” occurred at roughly midcentury for the United States and much of Europe, with a rapid decline in deaths due to infectious diseases. According to Omran, this epidemiological transition is characterized by a rise in the proportion of deaths first from trauma, then from diabetes, heart disease, and cancer. But what happens after the epidemiological transition? When these trends are reversed for some chronic diseases and cancers but not others, the question arises, why?

More recently, there has been a renewed emphasis on social determinants of health. McGinnis and Foege identified behavioral, social, and environmental determinants as the “actual causes of death in the United States,” while acknowledging that “socioeconomic status and access to medical care are also important contributors, but difficult to quantify.” For an earlier generation (1950s through 1970s), physician and demographic historian Thomas McKeown argued against any significant impact of either medical advances or even targeted public health programs, emphasizing instead the “invisible hand” of rising socioeconomic status as the explanation for improvements in population health outcomes.

Such root cause analysis perhaps answers the why question, but the cure is not always the inverse of the cause. A very different question is: what has been successful in improving health outcomes in the United States? In other words, addressing root causes may not be the only path to success. We therefore undertook this study to identify successes in improving cause-specific mortality rates in the adult US population, to identify innovations that enabled these successes, and then to identify patterns of success.

**METHODS**

Using national vital statistics mortality data, we identified disease categories that appeared on US government lists of leading causes of death in the US adult population in either 1950 or 2000, and that demonstrated at least a 50% reduction in age-adjusted death rates moving forward in time from their peak level to their lowest point between 1950 and 2000. Rates published by the National Center for Health Statistics (NCHS) have been age-adjusted to the standard year 2000 US population to negate effects of differences in the population’s age distribution over time. The NCHS also provides details on the comparability of diagnostic codes from one decade to the next, and has established explicit methodology for achieving comparability of diagnostic codes from 1950 to 2000, which included codes ranging from International Classification of Diseases, Seventh Revision (ICD-7) to ICD-10.

The time period chosen is somewhat arbitrary, but the first year that US mortality data were based on all 48 continental United States was 1933, and the years from 1933 to 1945 were marked by the effects of the Great Depression and World War II. Starting at midcentury therefore had the advantages of (1) availability of valid national mortality data, (2) absence of confounding by global war, and (3) ability to assess success in a time when chronic diseases, which still pose the greatest problems faced by Americans, had come to prominence.

All conditions identified were significant causes of death (mortality rates greater than 5 per 100000) at their peak, but some have declined so much as to no longer appear among leading causes of death in the United States. Because cancer as a leading cause of death represents many different diseases, and because different cancers have seen dramatically different trends over these decades, we reviewed separately the trends in cancer death rates...
for major categories of cancer as reported by the American Cancer Society, using the 2000 US standard population for age-adjusted reporting of cancer mortality rates.\textsuperscript{12}

We then undertook a review of the literature related to those cause-of-death categories that met our a priori criteria as “success stories” (i.e., a 50% reduction in age-adjusted mortality rates) to seek out any consensus on primary drivers of this success and to review the evidence allowing attribution of success to 1 or more causative factors. We then attempted to place these “success drivers” (especially as they related to diffusion of breakthrough innovations) in the public health sector, medical care sector, or both.

RESULTS

As shown in Table 1, within the broad category of “leading causes of death” reported in 2000 by the NCHS,\textsuperscript{13} there were 6 specific disease categories for which we could identify at least a 50% reduction in age-adjusted adult mortality from the peak mortality occurring during 1950 to 2000 to mortality rates in year 2000. Using the same strategy to look at 1950 data, we identified conditions that were still significant causes of death (mortality rates greater than 5 per 100000) in 1950, but that today no longer appear among leading causes of death in the United States. We thus identified 2 additional infectious diseases (tuberculosis [TB] and syphilis) and 2 forms of cancer (uterine or cervical cancer and stomach or gastric cancer) whose death rates dropped dramatically over these 5 decades.

The 9 cause-of-death categories that met these criteria as success stories in improving US health outcomes were as follows:

- Stroke (down 66.3%)
- Heart disease (down 56.1%)
- Uterine and cervical cancer (down 72.5%)
- Gastric (stomach) cancer (down 81.0%)
- HIV/AIDS (down 67.9%)
- TB (down 91.4%)
- Syphilis (down 100%)
- Influenza and pneumonia (down 55.9%)
- Accidents and unintentional injuries (down 55.3%)

In summary, 2 cardiovascular diseases, 2 cancers, 4 infectious diseases, and 1 category of injuries achieved this 50% mortality reduction. Although most of the success-story conditions showed a steady decline over the entire 5-decade period, HIV/AIDS mortality rose from zero to a peak of 16.3 per 100000 in 1995, then declined rapidly to 5.2 per 100000 by the year 2000.

DISCUSSION

Our results are consistent with the conclusions of the NCHS publication \textit{Health—United States}, 2005, which stated:

the [42%] reduction in overall mortality during the last half of the twentieth century was driven mostly by declines in mortality for such leading causes of death as heart disease, stroke, and unintentional injuries.\textsuperscript{14}(p11)
In reviewing the potential sources of these declines, we found that 7 of the 9 causes of death clearly required diffusion of new innovations through both public health and medical care channels, and could be counted as joint success stories consistent with a triangulation model of innovation plus public health plus medical care (Figure 1). We identified a clear pattern of joint success as exemplified in the 72.5% reduction in uterine and cervical cancer deaths, which resulted from the following:

- Epidemiological or clinical research providing breakthrough innovations such as the Papanicolaou (Pap) test,
- Public health education and outreach in the early diffusion phase, and
- Reliance on primary care and other medical practitioners for ongoing delivery.

Only 1 disease (gastric cancer) reflects a relatively pure nonmedical victory of rising social conditions, public health, and the infrastructure of effective sanitation, resulting in improvements in refrigeration, clean water, nutrition, and food safety. Another category (accidental injuries) might be counted as a relatively pure nonmedical victory of public health advocacy efforts in the arena of legislating seat belt use, safer cars, and safer highways, although we acknowledge the possibility of some lesser contribution of medical care via regionalized trauma care and emergency medical systems. We now explore each of these success stories in greater depth.

Vascular Disease

Heart disease and stroke mortality declined dramatically from 1950 to 2000. This decline is widely acclaimed as 1 of the great success stories of the last 5 decades in our nation’s health. What led to this decline? Was the success attributable largely to improvements in lifestyle, diet, and other cardiovascular risk factors? Was it widespread diffusion of the treatment of these risk factors into routine primary care practice? Can we attribute the success to changes in the health care system such as universal access to 911 emergency medical systems? Or was it advances in technology and specialty care of individuals with heart attacks and strokes? The answer appears to be “all of the above.”

Stroke—Stroke deaths in particular appear to have declined in response to reduction in 1 particular risk factor—high blood pressure; especially decreases in the prevalence of severe hypertension often associated with stroke. Age-adjusted prevalence of elevated blood pressure in the United States declined from 36.3% in the National Health and Nutrition Examination Survey I (NHANES I; 1971–1974) to 20.4% in NHANES III (1988–1991), and it declined in all demographic subgroups except older Black men. Mean systolic pressures also declined. Perhaps the most dramatic improvements were seen in the rates of achieving at least partial control of hypertensive blood pressure. Among persons being treated for hypertension, the proportion achieving a blood pressure of less than 160/95 mm Hg increased from 42% in NHANES I to 82% in NHANES III.

Outreach and screening campaigns that characterized high blood pressure as “the silent killer” were clearly a part of the success story, but only when coupled with the adoption of routine screening and treatment of high blood pressure in usual primary care practice. Cooper has cited the reduction in high blood pressure as a major cause of reductions in stroke and cardiovascular mortality, but also points out the challenges involved in transitioning from “classic public health strategies that have been applied to control microbial epidemics to a fully medicalized approach requiring individual doctor–patient encounters.” Clearly, the dominant setting for this treatment of high blood pressure is in primary care practices. According to 2005 data from the National Ambulatory Medical
Care Survey, almost 1 in 4 patients (22.8%) seen in physician office settings had hypertension, representing over 219 million ambulatory visits.17

Beyond the reach of public health and out-patient primary care, in-hospital mortality for stroke also declined significantly during the latter decades of the 20th century. The Minnesota Heart Survey found a 45% reduction in age- and sex-adjusted 28-day case-fatality rates for patients hospitalized for stroke from 1970 to 1985.18 Using national hospital discharge data, Fang and Alderman showed that the age-adjusted hospitalization rate for stroke actually increased by 18.6% from 1988 to 1997, whereas in-hospital deaths and case-fatality rates declined dramatically.19 Again, this suggests some significant role for improvements in in-hospital care (i.e., secondary and tertiary care) contributing to mortality declines, at least during the decades of the 1980s and 1990s. An alternative explanation, offered in an editorial accompanying the Fang and Alderman report, is the possibility that milder strokes were being detected more frequently by newer neuro-imaging techniques, potentially explaining the increased hospitalization rate and lower case-fatality rate.20

Heart disease—Reductions in heart disease death rates can also be attributed to the following triangulation model of success:

- Research and technology breakthroughs (e.g., insights into cardiovascular risk from the Framingham Heart Study,21 new drugs lowering blood pressure and cholesterol levels, and advances in interventional cardiology);
- Public health efforts (e.g., screening and media campaigns for hypertension as a silent killer, awareness of cholesterol as a cardiac risk factor, introduction of low-fat diets and lipid-lowering medications, and reduction in tobacco use); and
- Widespread diffusion of these breakthrough technologies and public health interventions in the routine practice of medicine (e.g., routine screening and treatment of hypertension and lipids in primary care settings, universal access to emergency medical systems, modern coronary care units, and secondary and tertiary care interventions for acute coronary syndromes).

A recent study of the relative contribution of each of these factors in decreasing cardiovascular deaths affirmed that there were multiple causes of this success. Hunink et al. were able to explain 92% of this decline in cardiovascular mortality from 1980 to 1990 in a multivariate model of secular trends during this period. They found that:

25% of the decline was explained by primary prevention, while 29% was explained by secondary reduction in risk factors in patients with coronary disease and 43% by other improvements in treatment in patients with coronary disease.22(p535)

Behavior changes achieved by the public health sector certainly played a role in this success. Cigarette smoking among men declined from 58% in 1960 to 28% in 2000, in part because of public health messaging and also legislative action (cigarette warning labels, limits on tobacco advertising, and more recent indoor clean air legislation). Dietary intake of saturated fat as a percentage of total calories, as well as total sodium intake and blood pressure levels, declined significantly during this period. Perhaps a greater investment in prevention could have achieved even greater success for our nation’s health, since mean body mass index (BMI; weight in kilograms divided by height in meters squared) and the prevalence of obesity and diabetes increased during these decades. Even so, age-adjusted cholesterol levels in the adult US population decreased from a mean of 222 mg/dL in 1960 through 1962 to a mean of 203 mg/dL in 1999 through 2002. This decrease began before the widespread use of lipid-lowering drugs; in fact, the greatest incremental decrease occurred from the period 1976 to 1980 (215 mg/dL) to the period 1988 to 1994 (204 mg/dL). From 1988 to 2002, the percentage of US adults taking cholesterol-lowering medications increased from 3.4% to
9.3% ($P<.01$), and age-adjusted mean low-density lipoprotein (LDL) cholesterol levels dropped from 138 mg/dL to 123 mg/dL.\textsuperscript{23}

A study of the decline in cardiovascular mortality in England and Wales found a prominent effect of both health promotion and clinical primary care, attributing two thirds of the reduction in mortality to declines in the prevalence of 3 risk factors: smoking, high blood pressure, and high serum cholesterol levels.\textsuperscript{24} This may reflect the more primary care–centered, less technology-intensive strategy of the British health care system.

The Atherosclerosis Risk in Communities Study (1987–1996) showed that although the incidence of first myocardial infarction remained relatively stable, the incidence of recurrent infarction declined, as did in-hospital deaths and the case-fatality rate for those hospitalized with myocardial infarction, emphasizing the growing importance of secondary prevention of recurrent myocardial infarction and therapeutic interventions to prevent in-hospital deaths.\textsuperscript{25}

Ergin et al., using US data from the NHANES Epidemiology Follow-Up Study, found that the decline in cardiovascular mortality from the period 1971 to 1982 to the period 1982 to 1992 could be attributed both to a decline in incidence of coronary events and in coronary artery disease case-fatality rates. Specifically, the case-fatality rate declined from 15.7% to 11.7% over these 2 decades. After adjustment for age, race, and sex, mortality rates declined 31%, incidence rates 21%, and case-fatality rates 28%. They concluded that “primary and secondary prevention and treatment contributed to the decline in cardiovascular disease mortality in the United States.”\textsuperscript{26}(p219)

\section*{Cancer}

\textbf{Cervical cancer}—Among cancers, we identified uterine and cervical cancers as the cause of over 8000 deaths in 1950, producing a mortality rate of 26.2 per 100000, which dropped dramatically over the next 5 decades. Declines in cervical cancer deaths are attributed to the introduction of the Pap test for screening and early detection and the effectiveness of treatments for precancerous dysplasia and early-stage cancers. No other change in clinical or behavioral risk factors appears to explain the decline. This is one of the purest examples of the explanatory model we propose in this study, which is that many of our nation’s health success stories derive from the dual-channel diffusion of breakthrough innovation via public health and primary care. In other words, cervical cancer rates dropped (1) because of a breakthrough innovation (the Pap test), (2) because public health professionals promoted this breakthrough to the public and helped women and their clinicians to believe that having a Pap test was important, and (3) because primary care professionals began performing Pap tests in routine practice. The magnitude of this primary care contribution now amounts to roughly 55 million Pap tests per year, plus follow-up for roughly 3.5 million women (6%) to prevent and treat cervical neoplasia.\textsuperscript{27} This triangulation model will also be relevant to any future success gained by widespread adoption of the human papillomavirus (HPV) vaccine in preventing cervical cancer.

\textbf{Gastric cancer}—Stomach cancer rates declined throughout the first 6 decades of the 20th century, which may be seen as a classic victory of public health and sanitation, specifically refrigeration, decreased food spoilage, and increased fresh food intake with declines in smoked foods, as well as more recently, perhaps, to decreased smoking rates. Rates of stomach cancer in various nations around the world still vary dramatically on the basis of socioeconomic factors and local access to electricity and refrigeration.\textsuperscript{28} Gastric cancer is also not easily amenable to either screening, early detection, or medical care once diagnosed, so the mortality declines are more likely to have come from environmental, hygiene, dietary, food safety, and public health improvements. Gastric cancer may be one of
the last examples of sanitation causing a decline in mortality in the first half of the 20th century, before the advent of the epidemiological transition.

**Tuberculosis and Syphilis**

TB and syphilis were among the top 5 leading causes of death in 1900. By 1950, TB was still responsible for nearly 34000 deaths (22.5 per 100000), whereas syphilis caused over 7500 deaths (5.0 per 100000). By the year 2000, deaths due to TB had decreased to 0.2 per 100000 and syphilis deaths to 0.0 per 100000 (41 actual deaths with syphilis as an underlying cause).

Declines in TB predated the availability of effective drug treatment, and early successes might be more attributable to basic hygiene and public health infection control strategies, including isolation of TB patients in workhouses and TB sanitaria. TB control is still a major focus of most state and local public health programs and requires both population-level efforts (education, skin testing, epidemiological surveillance, and tracing individuals who have had contact with TB patients) as well as clinical treatment. The line is even further blurred between public health and clinical medicine in that much of the screening and initial case finding for TB is generated in primary care practices by TB skin tests, whereas treatment (especially directly observed therapy) and follow-up may often occur in formally designated (and funded) public health TB clinics.

Prior to 1950, death rates from TB were typical of rates for diseases that responded dramatically to public health and sanitation measures, even without effective medical treatments, before the midcentury epidemiological transition, whereas the later decline in TB death rates may be more directly tied to medical care with effective anti-TB drugs. Among states participating in death certificate registration, the average annual death rate attributed to TB in the period 1901 to 1905 was 193.2 per 100000. Using complex time-series modeling techniques on the best available TB mortality trend data available for 1850 through 1950 (for Massachusetts), Catalano and Frank identified 2 specific innovations that led to lower-than-expected TB death rates at specific points in time.29 The first was a public health innovation evidenced by a statistically significant downward shift in TB mortality during the 1909–1913 time period, which they had predicted a priori would be the time period most likely to show the effects of isolating TB patients in TB sanatoria (the number of such facilities grew from 34 in 1900 to 536 by 1925).30 TB death rates in Massachusetts dropped more than fivefold from 1900 to 1950.

Again using Massachusetts data, Catalano and Frank found a second downward shift in TB death rates for the 5-year period from 1946 to 1950, which they had predicted a priori as the 5-year window in which the introduction of streptomycin and other effective anti-TB drugs might have a measurable impact. Throughout the United States, TB death rates declined nearly tenfold in just 20 years from 1950 (22.5 per 100000) to 1970 (2.6 per 100000).

Fairchild and Oppenheimer31 reviewed the debate on targeted public health interventions to reduce TB morbidity and mortality versus more general strategies targeting living conditions, nutrition, and poverty. They concluded that historical data support the effectiveness of 2 specific public health interventions (segregation of those infected with pulmonary TB and eradication of bovine TB), and suggested that “this literature weakens the arguments of McKeown … in favor of improved general well-being as the fundamental cause of the fall in TB mortality.”31(p1106) They also pointed out that in many ways the debate between public health interventions and general social improvements is a false argument, because public health includes both targeted interventions and broad social advocacy.
Syphilis control was made possible by a breakthrough innovation (penicillin) requiring a similar mix of both population-level public health efforts (education, blood testing, epidemiological surveillance, and outreach to those who had come in contact with syphilis cases) and clinical treatment. Routine screening and treatment both occur most commonly in primary care offices and clinics, outside of formal public health settings, but identified cases are subject to mandatory reporting. Syphilis and other sexually transmitted diseases could be controlled even more successfully if we could achieve a higher degree of consistency in screening and testing for high-risk patients in primary care settings. For example, 1 study found that only 25% of Medicaid clients with a primary diagnosis of gonorrhea or chlamydia received a syphilis test and 15% received an HIV test, even though both tests would be indicated according to Centers for Disease Control and Prevention (CDC) guidelines.\textsuperscript{32} In short, control of syphilis requires active engagement of both public health and primary care practitioners. Although syphilis deaths have been nearly eliminated, the incidence of primary and secondary syphilis is still significant, and no longer declining.\textsuperscript{33} Eradication of syphilis as proposed in the National Plan to Eliminate Syphilis will require not just parallel action but active collaboration.\textsuperscript{34,35}

**Influenza and Pneumonia**

Death rates from influenza and pneumonia declined from 48.1 per 100000 in 1950 to 23.7 per 100000 in 2000. Some of the early improvement may be attributed to improved sanitation and decreased crowding, but in recent decades the influenza and pneumococcal vaccines have played an increasing role in primary prevention. Attributing a mortality benefit to influenza vaccine is controversial. Eurich et al. found that most of the 51% reduction in mortality associated with influenza vaccine was due to confounding; although a vaccine effect was significant after control for age, sex, and comorbidities, it could be virtually eliminated by also controlling for socioeconomic and functional status.\textsuperscript{36} The clinical detection of pneumonia and treatment with effective antibiotics may also have decreased case-fatality rates for patients diagnosed and treated as outpatients or hospitalized with pneumonia, although, again, this is difficult to quantify. A negative form of evidence is provided by Price et al., who found a 50.6% increase in winter pneumonia mortality, adjusted for influenza incidence, to be associated with a 30% decrease in community rates of antibiotic prescribing for lower respiratory tract infections.\textsuperscript{37} Assuming that both vaccines and antibiotics are relevant to this US success story in reducing deaths due to influenza and pneumonia, we can see again the 3 essential elements: breakthrough innovation (immunization and antibiotics), dissemination of the innovation through public health, and application of the innovation by primary care practitioners.

**HIV/AIDS**

Mortality rates from HIV/AIDS were rising in the United States until 1996, when the introduction of protease inhibitors began to reverse this trend. Since then, widespread adoption of highly active antiretroviral therapy (HAART) has led to dramatic declines in HIV-related deaths.\textsuperscript{38,39} This success story again follows the pattern of a breakthrough treatment (HAART), a strong public health component (risk reduction strategies as well as community-level screening), and a medical care component (diagnosis, HAART, and comprehensive bio-psychosocial care models) delivered through both primary care and specialty medical providers. Unfortunately, this example also reveals the potential inequalities inherent in the diffusion of innovation. Although mortality rates declined for both African American and White segments of the population in the decade following release of the HAART drug regimens, the Black–White mortality gap (expressed as a mortality rate ratio) actually increased from 1996 through 2006.\textsuperscript{40} The widening of the Black–White HIV/AIDS mortality gap corresponds with the well-documented disparities in
receipt of the life-saving HAART, even in segments of the population in which both racial groups had exactly the same Medicaid card and drug formulary.\textsuperscript{41}

### Unintentional Injuries

Motor vehicle injuries and injuries not involving motor vehicles both declined during this period. The reduction in these deaths could be counted as primarily a success of public health promotion, public health advocacy, and auto safety legislation, starting with the Highway Safety Act of 1966 (Pub L No. 89-564, 80 Stat 731) and the National Traffic and Motor Vehicle Safety Act of that same year (Pub L No. 89-563, 80 Stat 718). The Centers for Disease Control and Prevention specifically claim that the reduction in motor vehicle accidents is a “20th century public health achievement,” citing a 90% decrease in the annual death rate, from 18 per 100 million vehicle miles traveled in 1925 to 1.7 per 100 million vehicle miles traveled in 1997.\textsuperscript{42}

Attention to both highway safety and vehicle safety provided the physical improvements necessary to achieve these reductions, which often were tied to innovations such as air bags and breakaway utility poles, or innovative improvements in seat belts and bicycle and motorcycle helmets. From this perspective, public safety legislation drove innovation, rather than the converse. Combining legislative mandates with educational reinforcement led to positive changes in driver behaviors such as use of seat belts, child car seats, and motorcycle helmets. This combination also targeted negative behaviors such as driving under the influence of alcohol and speeding. One can attribute all of these successes to public health broadly defined, if we acknowledge that public and legislative advocacy is 1 of the essential tools of improving population health (i.e., public health) at the state or national level.\textsuperscript{43}

Attributing public health efforts to improve highway and vehicle safety as the source of these mortality reductions is not without controversy. Richter et al.\textsuperscript{44} pointed out that much of the drop in death per vehicle miles traveled occurred prior to 1966—before highway and motor vehicle safety legislation—and argue that the CDC report did not adequately account for reductions in average travel speeds related to traffic congestion. Still, their recommendations for the future rely on new highway safety laws and their enforcement, specifically focusing on lowering speed limits and enforcing them more consistently.

The most common causes of accidental death not due to motor vehicle accidents include falls, drowning, poisoning, and burns. Reductions in deaths from these causes again may be attributed to consumer-safety legislation and product engineering. Specific studies of the role of medical care in the 1980s and 1990s found little evidence that improvements in clinical treatment influenced case-fatality rates for either burn injuries or drowning.\textsuperscript{45,46}

Evidence of reductions in case-fatality rate for certain clinical trauma syndromes (e.g., hemorrhagic shock, brain injury, etc.)\textsuperscript{47} suggests that some of this success might at least conceivably be attributed to certain clinical advances and developments in the health care delivery arena. These include the development of a universal 911 system, regional trauma centers, emergency medical services, prevention counseling in primary care practices, and advances in trauma care.\textsuperscript{48} For example, in a study of 18103 trauma patients, Cudnik et al. found that, compared with patients taken to Level II centers, those taken to Level I centers had more severe injuries, more penetrating injuries, and more complications, but had similar unadjusted mortality and, in adjusted analyses, lower mortality (odds ratio=0.75).\textsuperscript{49} A study of 12254 severely injured patients from the National Trauma Data Bank showed a similar level of benefit for Level I trauma centers in functional outcomes.\textsuperscript{50} Even so, public policy, engineering, and legislative interventions to achieve safer highways, safer cars, and less impaired drivers appear to have had the greatest impact.
Limitations

This study reflects our effort to summarize broad trends in seeking to understand 5 decades of differential patterns of mortality reduction in different disease conditions. We have tried to be transparent and explicit about our a priori methodology for selecting the “success” conditions, to reflect the best available evidence on contributing factors to mortality reductions, not to overreach in assuming that past patterns of success are the only path to future success, and to acknowledge the many limitations of our analysis.

For example, there are many different ways to lump or split causes of death into categories. Any method is subject to differences of opinions. We have chosen to use the “Leading Causes of Death” lists created by the NCHS, since these are routinely published in documents such as Health of the United States and used not only by public health officials but also by policymakers for understanding the big picture of health in the United States. We set out with a transparent and explicit methodology to use these lists to identify large-category causes of death that might or might not have achieved the 50% threshold of mortality reduction. The 1 exception we made (also a priori) was to treat cancer not as 1 disease but as multiple diseases with very different trend lines for mortality over the past half century.

Any definition of success, and especially a numeric threshold for success, is arbitrary. We acknowledge this as a limitation. The key point is that we defined the success threshold in advance and then dealt with whichever causes of death fell out of that a priori definition. Other studies have used a similar measure. For example, Djulbegovic et al. used a 50% reduction in mortality as the measure of success or breakthrough in phase 3 cancer clinical trials conducted over a similar time period—that is, the past 50 years.51

Other measures could be used in similar analyses. One alternative would be a different measure of mortality that reflected the impact of conditions causing death at younger ages or gains in productive years of life, such as years of potential life lost before age 75 or improvements in age-specific rather than age-standardized mortality. Improvements in age-adjusted death rates and years of potential life lost before age 75 simply measure 2 different kinds of success; we chose age-adjusted death rates a priori as the measure most frequently cited in official statistics on our nation’s health. Other alternatives include the World Health Organization lists of leading causes of “burden of disease,” in which mental health conditions such as depression are much more prominent. Measures of improvements of morbidity or burden of disease might lead to further understanding, but limitations in the comparability of data from 1950 to 2000 make a quantitative measure of this beyond our technical abilities. Use of age-adjusted death rates is more typical for long-term trend analyses at a national or international level.

Our method of review also favors success stories affecting the entire population. This may unintentionally give lower weight to targeted public health interventions that focused on certain subpopulations (such as Pap tests delivered to low-income women in public health clinics). The boundary between public health and medical care is often blurred for uninsured, low-income, and other vulnerable populations, especially in communities where public health departments have chosen to provide direct clinical services. The triangulation model does not undervalue the contribution of public health in this circumstance, but rather celebrates the more explicit synergies that can be achieved when public health and primary care achieve higher levels of integration.

Conclusions

Of the 9 cause-of-death categories that achieved at least a 50% mortality reduction, 7 clearly involved clinical or epidemiological research innovation, which then diffused or became
operationalized through both public health and medical care channels (Table 2). In short, they could be counted as joint success stories not attributable to interventions in a single sector, or changes in a single behavioral cause or social determinant. Only the category of unintentional injuries could be counted as primarily a success of public health promotion and legislative advocacy, and gastric cancer as a success of classic public health sanitation. The success of the Pap test in reducing cervical cancer deaths, of hypertension treatment in reducing stroke deaths of HAART in reducing AIDS deaths show a clear pattern of joint success—research providing breakthrough insights and technologies; public health providing education, outreach, and screening (especially in the early diffusion phase); and primary care and other medical practitioners providing day-to-day care delivery.

For this model, we assume social determinants or McKeown’s “invisible hand” of improved overall living conditions as a background factor that would apply to general mortality reductions, and that perhaps had a significant impact on broad mortality reductions due to infectious diseases in the pre-antibiotic era. In this study, we chose to ask which diseases had the greatest mortality declines after the epidemiological transition, and then to understand why. If success in achieving mortality reductions for different diseases is affected by social determinants, we must then understand that social determinants apply differently to different diseases and different segments of the population.

The general US population has already benefited substantially from rising social status and improved living conditions, so the remaining health gains to be achieved in improving social determinants in the United States might come specifically from decreasing social inequalities, which prevent some segments of the population from receiving the full benefit of health improvements. Further research is needed to explain how these social determinants affect mortality disparities differently for disease categories that are experiencing significant mortality declines versus conditions that are not declining.

We see our triangulation model as operating through this filter of social determinants. In fact, Phelan et al. have made a powerful argument that it is the very conditions we have identified as most consistent with this triangulation model (i.e., those conditions for which we have effective public health interventions and effective screening, diagnosis, and treatment modalities) that are most likely to demonstrate significant health disparities tied to social determinants, which Phelan et al. refer to as a “fundamental cause.” In their words, “evidence regarding several major killers indicates that disparities arose when new knowledge and technology gave us the capacity to prevent death from those diseases.”

One subset of social inequality—racial and socioeconomic inequalities in health insurance coverage—is a major barrier to life-saving medical care and breakthrough innovations. The partial progress of the 1960s in implementing health coverage for the elderly (Medicare) and for specific subgroups of the poor (Medicaid coverage of low-income children, mothers, and disabled persons) created opportunities for increased health equity for some, even while excluding others (e.g., women without children and nonelderly men). This Medicare–Medicaid surge of partial progress in health care coverage was embedded in a larger wave of social progress in civil rights, child education, and neighborhood-level community economic development. In other words, public health, social determinants, civil rights, and universal medical care were not seen as competing interests. This was a moment in history that illustrated the potential synergies in aligning efforts in progress toward health equity, health care coverage, economic opportunity, social equity, and civil rights.

It is not clear whether medical care has made such a prominent contribution to the post-1950 successes in mortality reduction because it is inherently powerful or just because we put so
much of our health spending into it. We might arguably have achieved even greater or more long-lasting reductions in mortality if we had spent a larger portion of US health expenditures on public health and health promotion (primary prevention) rather than on secondary and tertiary prevention, or if we had achieved greater equity in social determinants.

One unintended consequence of our model might be that it undervalues the ongoing contribution of public health to our nation’s health status, over and above the disease conditions listed here. In other words, the ongoing maintenance of the success of the previous half century is an important success in itself, and should not be taken for granted. The maintenance of safe water, safe food supply, clean air, clean water, childhood immunization rates, and TB control, among other things, is essential to maintaining the fragile health gains of the epidemiological transition, and can be lost by any nation that does not value them (as in war-torn countries with reemergence of cholera, or even outbreaks of vaccine-preventable illnesses when public health infrastructure is allowed to decline). In one sense, most of the successes of the first half of the 20th century in reducing deaths due to communicable diseases must be counted as continuing successes in that they require ongoing public health and sanitation infrastructure to maintain low mortality for such diseases. There is also a long and reemerging tradition in public health of addressing social determinants by promoting education, improved housing, and access to nutritious food as public health initiatives on a par with immunization campaigns.

Our explanatory model of triangulation has recently been cast as “translational research”—research designed to move innovation more rapidly into widespread application in real-world, day-to-day practice. Our analysis demonstrates that translation is not a new concept, but rather a reframing of the process needed to bring together basic research, public health, and medicine, especially primary care. All 3 elements are needed for the continued improvement of our nation’s health.

We therefore close with a consideration of policy directions that could plausibly follow from this analysis. First, it is necessary to build on these successes to leverage the triangulation model more explicitly (consciously)—that is, by creating explicit partnerships between public health and primary care at both the national level (CDC plus Health Resources and Services Administration) and local level (local health departments plus community health centers plus private-sector medical practices); creating public health and medical care systems integration in geographically defined health outcome areas; and investing in key social determinants most likely to bring the benefits of triangulation to high-disparity segments of the population.

Second, focus on investments that target social determinants to achieve success more equally across all segments of the population and to broaden the range of causes of death in which we achieve success beyond only those causes of death that are most amenable to medical care interventions.

Third, achieve universal access to routine medical care and breakthrough innovations not only through universal health insurance coverage (necessary but not sufficient), but also by ensuring a community-oriented primary care safety net for vulnerable and underserved populations in every community in America.

Fourth, increase the proportion of US health spending on prevention, health promotion, and public health infrastructure relative to medical care expenditures to achieve success more equally across all segments of the population and across a broader range of causes of death.
Fifth, invest heavily in models of bidirectional discovery, in which researchers, community health professionals, and community representatives together identify relevant research questions and potential breakthrough innovations, rather than using communities as laboratories for investigator-initiated ideas. Invest also in real-world effectiveness research infrastructure (often referred to as T2 translational research, as distinct from bench-to-bedside T1 translation). Such research infrastructure includes long-term, community-based, participatory research partnerships and practice-based research networks, to speed diffusion of breakthrough innovations especially to communities in greatest need.

In summary, triangulation is a potential explanatory model for these health success stories. The model reminds us that all 3 stakeholder groups—researchers, public health professionals, and medical practitioners—have a common stake in improving health outcomes for the American people, and even share joint success stories. Achieving further reductions in mortality for these conditions, as well as for conditions that have not yet declined, will continue to require involvement of all 3 sectors in common purpose. Too often, the competition for resources leads us to work more in parallel than in partnership. How much more could we accomplish together, if research and public health and clinical care sectors all worked consciously, collaboratively, and pro-actively in partnership for America’s health?

Acknowledgments

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References


FIGURE 1.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Year 1950 Rate</th>
<th>Highest Rate (Peak Year)</th>
<th>Lowest Rate (Trough Year)</th>
<th>Year 2000 Rate</th>
<th>Decline From Peak Year, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>180.7</td>
<td>180.7 (1950)</td>
<td>60.9 (2000)</td>
<td>60.9</td>
<td>66.3</td>
</tr>
<tr>
<td>Heart disease</td>
<td>586.8</td>
<td>586.8 (1950)</td>
<td>257.6 (2000)</td>
<td>257.6</td>
<td>56.1</td>
</tr>
<tr>
<td>Gastric cancer</td>
<td>24.2</td>
<td>24.2 (1950)</td>
<td>4.6 (2000)</td>
<td>4.6</td>
<td>81.0</td>
</tr>
<tr>
<td>HIV</td>
<td>...</td>
<td>16.3 (1995)</td>
<td>5.2 (2000)</td>
<td>5.2</td>
<td>67.9</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>25.5</td>
<td>25.5 (1950)</td>
<td>0.2 (2000)</td>
<td>0.2</td>
<td>91.4</td>
</tr>
<tr>
<td>Syphilis</td>
<td>6.1</td>
<td>6.1 (1950)</td>
<td>0.0 (2000)</td>
<td>0.0</td>
<td>100</td>
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<tr>
<td>Influenza and pneumonia</td>
<td>48.1</td>
<td>48.1 (1950)</td>
<td>23.7 (2000)</td>
<td>23.7</td>
<td>50.7</td>
</tr>
<tr>
<td>Unintentional injuries</td>
<td>78.0</td>
<td>78.0 (1950)</td>
<td>34.9 (2000)</td>
<td>34.9</td>
<td>55.3</td>
</tr>
</tbody>
</table>
TABLE 2
Contributors to America’s Health Success Stories: 1950–2000

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>66.3</td>
<td>Antihypertensive drugs</td>
<td>Blood pressure education and awareness campaigns</td>
<td>Blood pressure treatment in primary care practice settings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clinical trials for prevention and acute treatment of stroke and transient ischemic attacks</td>
<td>Community blood pressure screening</td>
<td>Antiplatelet drugs</td>
</tr>
<tr>
<td>Heart disease</td>
<td>56.1</td>
<td>Epidemiology and risk factor insights</td>
<td>Blood pressure education and awareness campaigns</td>
<td>Blood pressure treatment in primary care practice settings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antihypertensive drugs</td>
<td>Blood pressure education and awareness campaigns</td>
<td>Anticoagulant drugs, especially for chronic use in atrial fibrillation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lipid-lowering drugs</td>
<td>Low-salt, low-fat diets</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clinical trials of medical and surgical interventions for acute coronary disease and prevention of recurrent infarction</td>
<td>Low-salt, low-fat diets</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regional EMS</td>
<td>Low-salt, low-fat diets</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decreased smoking</td>
<td>Low-salt, low-fat diets</td>
<td></td>
</tr>
<tr>
<td>Uterine and cervical cancer</td>
<td>72.5</td>
<td>Pap test</td>
<td>Public education and awareness</td>
<td>Routine Pap testing in primary care and OB/GYN settings</td>
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<tr>
<td></td>
<td></td>
<td>After 2000: HPV vaccine</td>
<td>Pap tests and STD screening clinics</td>
<td></td>
</tr>
<tr>
<td>Gastric (stomach) cancer</td>
<td>81.0</td>
<td>Refrigeration</td>
<td>Refrigeration</td>
<td>Condom and safe sex counseling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fresh food supply chain</td>
<td>Food sanitation</td>
<td></td>
</tr>
<tr>
<td>HIV/AIDS</td>
<td>67.9</td>
<td>Identification of AIDS virus</td>
<td>Public education and awareness</td>
<td>Routine testing in primary care settings</td>
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<tr>
<td></td>
<td></td>
<td>Development of protease inhibitors and other antiretroviral drugs</td>
<td>Condom and safe sex education</td>
<td>HIV/AIDS specialty clinics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HAART</td>
<td>Anonymous testing</td>
<td>Widespread adoption of effective antiretroviral drugs</td>
</tr>
<tr>
<td>TB</td>
<td>91.4</td>
<td>Anti-TB drugs</td>
<td>Public clinics and access to antiretroviral drugs</td>
<td>Routine TB skin testing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clinical trials for treatment of drug-resistant TB</td>
<td>TB treatment and directly observed therapy</td>
<td>Prophylactic treatment of positive PPD tests</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Syphilis</td>
<td>100</td>
<td>Serum screening tests</td>
<td>Surveillance and contact tracing</td>
<td>Drug treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antibiotics</td>
<td>Local public health (surveillance, contact tracing, etc.)</td>
<td>Routine screening and treatment in primary care practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>STD clinics</td>
<td></td>
</tr>
<tr>
<td>Influenza and pneumonia</td>
<td>55.9</td>
<td>Antibiotics</td>
<td>Surveillance and tracking</td>
<td>Routine use of antibiotics in primary care and emergency department settings</td>
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<tr>
<td></td>
<td></td>
<td>Influenza and pneumococcal vaccines</td>
<td>Adult immunization programs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Public financing (Medicare, Medicaid) for influenza and pneumonia vaccines</td>
<td></td>
</tr>
<tr>
<td>Unintentional injuries</td>
<td>55.3</td>
<td>Crash-dummy testing</td>
<td>Seat belt laws</td>
<td>Seat belt counseling in primary care practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auto safety innovations (windshields, fuel tanks, seat belts, bumpers, crush zones, etc.)</td>
<td>Auto safety regulations</td>
<td>Routine preventive counseling (bicycle helmets, car seats, etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55 mph speed limit</td>
<td>911 emergency medical systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Public education (seat belts, bicycle helmets, etc.)</td>
<td>Regional trauma centers</td>
</tr>
</tbody>
</table>

*Note.* CCU = coronary care unit; EMS = emergency medical systems; HAART = highly active antiretroviral therapy; HPV = human papillomavirus; ICU = intensive care unit; OB/GYN = obstetrics/gynecology; Pap = Papanicolaou; PPD = purified protein derivative; STD = sexually transmitted disease; TB = tuberculosis.