The S-curve discontinuity theory predicts the path towards a "well" society and increased longevity

Lisa B.E. Shields[a], Tyler A. Gertz[b], Kenneth C. Wilson[b], Ginger L. Figg[b], Steven T. Hester[b], Joshua T. Honaker[b],*

[a] Norton Neuroscience Institute, Norton Healthcare, Louisville, KY 40202, USA
[b] Norton Medical Group, Norton Healthcare, Louisville, KY, 40241, USA

ABSTRACT

The logistic function or logistic growth curve is an "S" shape (sigmoid curve) that has been applied to numerous fields, including geology, physics, biology, mathematics, chemistry, economics, sociology, oncology, and statistics. The S-curve initiates with exponential growth, followed by slowing of growth as saturation occurs, and completion of growth at maturity. The S-curve follows the law of natural growth with a limiting factor, whether it be a competition for resources, investigation and demand for new products, or an economic bubble. The concept of the S-curve has been utilized in medicine to describe the advancements in the 20th century based on the diagnosis and treatment of disease (the "illness" curve [first S-curve]) and predict the future focused on disease prevention and health promotion (the "wellness" curve [second S-curve]). Herein, we propose a third S-curve that we are labeling the "longevity" curve.

Multiple S-curves in business

The principle of the S-curve has been applied to business where a company initially starts with modest growth and then enters a period of rapid growth until it reaches the period of maximum growth [1]. A saturated market then follows when maturity is reached with shrinking returns, followed by a plateau and a minimal decline. The inflection point for a company occurs when there is a transition to a new S-curve [2]. The "discontinuity" period between the two S-curves is marked by a stagnating or decline in the growth of technology. The new S-curve materializes and exponentially grows as new technology is perfected. Companies are able to view their likely potential by utilizing the S-curve theory [3]. Interestingly, the evolution of technology has been described as multiple and successive S-curves with irregular step functions rather than a single S-curve [4,5]. The term "jumping S-curves" refers to a successful progression to new growth opportunities [3]. For example, UPS jumped S-curves numerous times when it transitioned from a messenger service to a business delivery service to a public parcel delivery service. Additionally, the world's leading technology company Apple has perfected the art of jumping S-curves by altering its focus from profitability to quality of products with its iPod, iPhone, and iPad. The momentum that UPS and Apple has generated has shortened each subsequent S-curve.

Use of the S-curve discontinuity theory to illustrate the "chaotic" period between the "illness" and "wellness" curves of healthcare

We previously described Adler's application of the S-curve to medicine and the theory of S-curve "discontinuity" to explain healthcare's past and predict its future [6–9]. The medical field prior to the 20th century lacked standardized care and quality. The initial steep "illness" S-curve was characterized by antibiotics, vaccinations, anesthesia, imaging capabilities, and surgical and technological advances (Fig. 1). This S-curve plateaued at the end of the 20th century due to a host of factors, including high healthcare costs, growing chronic diseases, bureaucracies, unnecessary medical testing, large malpractice claims, and abuse of the system by patients and physicians [8].

Adler predicted the start of a second "wellness" S-curve with a focus on disease prevention and health promotion [8]. The "discontinuity" period reflects the overlapping of the two S-curves and a shift from one curve to the next. This "chaotic" phase, known as "discontinuity" to Adler, is marked by a deterioration in healthcare progression and is primarily represented by chronic disease and rising healthcare costs. Several other competing factors also play a significant role during this

Illness Curve
- Antibiotics and vaccinations
- Anesthesia
- Imaging capabilities
- Surgical and technological advances

1st Chaotic Period
- Chronic disease
- Rising healthcare costs
- Electronic health records
- Transition from volume to value
- Alteration in physician employment model
- Reimbursement challenges
- Population health

Wellness Curve
- Genomics
- Chronic care
- Gene therapy
- Management of kinetic injuries
- Integrative medicine
- Technology
- Nanomedicine
- Immune system modulation

2nd Chaotic Period
- Social justice, moral/ethical dilemmas
- Allocation of resources
- New unknown diseases that develop when people are more well
- Global inequality for "wellness" resources

Longevity Curve
- Replacing human organs
- Nanomedicine
- Genomics
- DNA manipulation
- Optimal nutrition
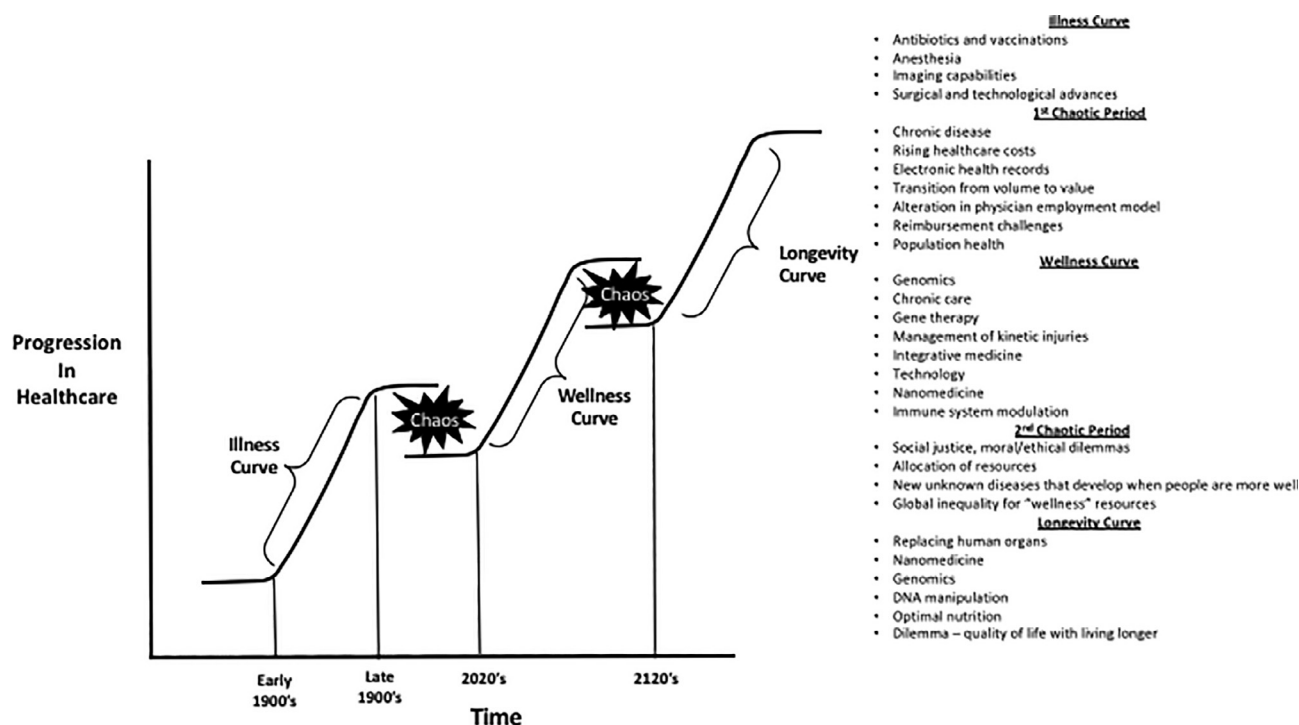- Dilemma – quality of life with living longer

Fig. 1. Utilizing the S-curve discontinuity theory in healthcare, featuring the "illness", "wellness", and "longevity" curves.

period, including the chronic disease, electronic health record, the transition from volume to value, alterations in the physician employment model, reimbursement challenges, and population health (Fig. 1). We predict that the "chaotic" period started in the late 20th century and will extend until the 2020's decade. The efforts to ameliorate the detrimental elements of the "chaotic" phase will spur the momentum to initiate the transition to the next "wellness" S-curve.

Frist describes that American health care is currently at a crossroads, with the innovative forms of technology dramatically enhancing lives while escalating costs and disparities in health care pose hurdles to transforming healthcare [10]. This "crossroads" is similar to our "chaotic" phase where advancements and challenges create a tumultuous period. Frist's solution is a patient-centered, consumer-driven, and provider-friendly healthcare system [10].

Use of the S-curve discontinuity theory to predict the "wellness" phase of healthcare

After the "chaotic" phase, there will be a steady rise and steepness of the next S-curve which will represent the "wellness" curve. The culmination and plateau of the second S-curve is attained when most people in society are well. What will healthcare look like when the majority is well? Will there be hospitals, emergency clinics, and surgeons when no one is suffering from a medical illness or requires surgical intervention? Is it possible for most members of society to be well when individuals choose better lifestyles? Individuals with a healthy lifestyle (exercise, healthy eating, no smoking) are more likely to promote, encourage, and maintain a "well" society, while those with vices will compromise this goal of a completely "well" society. Social incentives may reward the former group for their positive decisions, whereas the latter group may face repercussions for their unhealthy choices, such as increased taxes on carbonated beverages and cigarettes. Advances in genomics and technology will also ease entry into the wellness phase.

Obesity is an obstacle to progressing to the wellness curve. Obesity poses a significant global health challenge due to its escalating prevalence in both adults and children and the associated health risks. The 2013 Global Burden of Disease Study reported that the prevalence of overweight and obese children and adults worldwide rose by 47.1% and 27.5%, respectively, between 1980 and 2013 [11]. Childhood obesity is associated with an increased risk of obesity, cardiac disease, Type 2 diabetes, stroke, and premature morbidity and mortality in adulthood. Furthermore, obese children have a higher risk of bone and joint problems, sleep apnea, and social and psychological problems.

A focus on mental and behavioral health in childhood is another key strategy for promoting the wellness curve. Good decision making skills need to be nurtured and secured in childhood, with a focus on mental and behavioral health. The key factor in minimizing chronic disease in adults is targeting children through a multifaceted approach. In Felitti and colleagues' Adverse Childhood Experiences (ACE) study, a host of adverse childhood experiences (psychological, physical, or sexual abuse; violence against mother; or living with household members who were substance abusers, mentally ill or suicidal or ever imprisoned) were compared to measures of adult risk behavior, health status, and disease [12]. Adults who experienced four or more categories of childhood exposure compared to those who had experienced none had a 4- to 12-fold increased health risks for alcoholism, drug abuse, depression, and suicide attempt [12].

In addition to an emphasis on obesity and mental behavior, a focus on the payment system is warranted. Established in 2015, the Merit-based Incentive Payment System (MIPS) is a Medicare physician payment system that promotes value-based payments [13]. It encompasses four components: (1) quality (Physician Quality Reporting System); (2) cost (value-based payment modifier); (3) Advancing Care Information based on the Medicare HER incentive program; and (4) improvement activities. This physician payment model emphasizes value versus volume which encourages continuity and quality of patient care. One of the primary goals of the MIPS program is to curtail the overwhelming burden of chronic disease on society with its associated morbidity, mortality, and financial ramifications. Through this realignment of finances and resources with accompanying penalties issued by the Centers for Medicare and Medicaid Services (CMS), the primary outcomes are healthier patients with better experiences, increased quality, and improved safety.

The transformation from an "ill" society to one which is "well" requires a multi-faceted approach. By having government and insurance companies reward physicians for their patients who are "well" and penalize physicians whose patients remain "ill" sends a powerful message. Through the heightened transparency of healthcare, patients will be able to view physicians' statistics to reveal those with the healthiest patients who require fewer hospital readmissions and need a lesser amount and are more compliant with their medications. Every opportunity to decrease chronic disease should be undertaken, including transporting patients to their physician visits, installing remote monitoring equipment, and arranging home health visits. The Apple Iwatch is a perfect tool for supervising personal behavior with its health and fitness data application. Furthermore, encouraging faith based organizations will improve individuals' spiritual side.

Prevention of chronic disease in the early 21st century is a high cost with minimal immediate return. Striving to attain a society where its members are largely "well" will require the efforts of government, insurance companies, and individual patients as well as an exponential investment in technology. With the application of the "wellness" S-curve to medicine, high performing, superior quality, and safe healthcare systems will abound with the implementation of chronic disease management, genomics, genetic engineering, management of kinetic injuries, antioxidants, integrative medicine, nanomedicine, cyber-health care and medicalbots (nonhuman intelligence agents), and immune system modulation (Fig. 1). Implantable nano devices will provide continuous real-time monitoring of a patient's condition, permitting the early recognition and aggressive treatment of life-threatening conditions while increasing accuracy and reducing costs [14]. With the advent of CRISPR/Cas9 technology, editing genomes by altering DNA sequences and modifying gene function is possible [15]. CRISPRs are stretches of DNA which may be cut by the enzyme Cas9, resulting in corrections of genetic defects, treatment and prevention of disease transmission, improving cancer therapies, and advancements in the food and agriculture industries [16,17]. Ethical considerations have been raised regarding the use of CRISPR, specifically, genetic editing of human embryos and reproductive cells such as sperm and eggs known as germline editing [18]. The question arises as to whether it is appropriate to select and manipulate genes in an embryo which will produce a healthier newborn without the future disease burden.

The allocation of funds in the "wellness" phase will vary drastically compared to the "illness" and "chaotic" phases. The "wellness" industry will flourish with fitness and organic clubs as well as more smoke-free environments. Instead of accelerating the aging process with fatty foods, smoking, and lack of exercise, the "well" society will promote a balanced lifestyle marked by supreme nutrition, sleeping and exercising more, sunscreen to protect again harmful sun rays, drinking a larger amount of fluoridated water, social interaction, and meditation. Retirement homes will no longer be stoic locales with mentally and physically inactive inhabitants. Dynamic retirement communities will feature cognitive and physical exercise classes to prevent Alzheimers disease and early onset dementia. The brain will be kept as healthy and active as the body, and the quality of life will be greatly enhanced. The mindset of "wellness" in society will spread across the age spectrum. As people incorporate healthy eating and exercise into their daily lifestyles, there will be a societal pressure to stay thin. Not only will the elderly revisit the stamina of their youth, but the younger generations including children and adolescents will welcome the "wellness" that permeates society.

Introduction of the "longevity" curve

The plateau of the "wellness" phase will be reached when the majority in society is well and when physiology prevents humans from living any longer. There will be limits to the human lifespan until new and innovative genetic breakthroughs with manipulation of DNA serve as the catalyst for a third S-curve which we have coined the "longevity"

curve. Potential features of the third "longevity" S-curve include replacing human organs, DNA manipulation such as turning off the biological triggers that lead to cell death, genomics, nanomedicine to end aging and reverse one's current biological age, and utilizing the brain's capabilities to the fullest (Fig. 1). Novel approaches to defy the aging process, such as slowing neurodegeneration, will promote longevity. The key is to live with vim and vigor at a significantly older age. Similar to the first "discontinuity" period between the first two S-curves, there will be a second "discontinuity" period between the second and third S-curves. This second "chaotic period" may be reflected by social justice issues, moral and ethical dilemmas, allocation of resources as people live to an older age, new unknown diseases that develop when individuals are more well, and global inequality for "wellness" resources (Fig. 1). In this respect, the individuals who practice a "wellness" regimen will survive while the others will not be benefit from the "wellness" movement.

The life expectancy in the United States for both sexes and all races was 78.8 years in 2014 [19]. We predict that the life expectancy will be significantly higher by the plateau of the third "longevity" S-curve with optimal genetics and nutrition. The person with the longest confirmed human lifespan lived to age 122 years [20]. As of 2015, there have been approximately 1,700 verified supercentenarians, specifically, one who has lived to or passed his/her 110th birthday [21]. This "radical life extension" with a resulting global overpopulation raises numerous moral and ethical concerns, such as the allocation of resources when people live significantly longer and terminating elderly individuals' lives or limiting reproduction [14]. The biogerontologist Aubry De Grey believes that people will gain a new level of respect for one another, the environment and earth, and for one's own body and consequences of one's actions as lifespans are considerably extended [14]. It has been suggested that the end of aging and reversal of one's current biological age to any new age may ensue, resulting in "ageless bodies" [14]. Deaths will more likely result from accidents and suicide instead of natural disease, suggesting that the life expectancy of at least one thousand years is expected [14]. We believe that the life expectancy could reach an average of 100 years and a maximum of 150 years within the next century.

The quality and value of life should be considered when individuals reach an age when they are "well" with an absence of disease yet do not possess the vim and vigor of their younger years. Will there be a time when an elderly person no longer wants to live and is ready to die?

Conclusion

We all strive to maintain the fountain of youth as we age. We may be able to predict the future when it comes to our potential to achieve such, thanks to the theory of S-curves in healthcare. Applying the technological jumping S-curve premise to medicine, we speculate that the second "wellness" S-curve will accelerate and be shorter than the initial "illness" S-curve. We hypothesize that the first S-curve will last approximately 80–100 years from the early 20th century until the 2020's decade and that the second S-curve will terminate before the early 22nd century. Just as Apple altered its business strategy from profit to value of products, healthcare has transformed from volume to value of patient care. There is a need for societal priorities to incentivize wellness behavior and broader programs. The transformation of medicine has shifted from the "illness" curve where sick people become well to the "wellness" curve where people remain healthy but are limited by human physiology to the "longevity" curve where the current limits of average life expectancy may actually be significantly extended.

Acknowledgment

Conflict of interest statement

The authors have no competing conflicts of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.mehy.2018.09.006.

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