The S-Curve Discontinuity Theory Applied to Medicine to Explain Healthcare's Past and Predict Its Future

Developed in 1845 by Verhulst, the logistic growth curve is an "S" shaped sigmoid curve referring to the self-limiting population growth in ecology. The initial growth stage is exponential, followed by slowing of growth as saturation begins and ending of growth at maturity. In geology, an uncertain period exists at the upper horizontal arm of the S-curve when a species utilizes its available resources and either extinction or evolution by natural selection results.

The S-curve has been used in biology, physics, mathematics, chemistry, economics, sociology, oncology and statistics. The S-curve theory has been applied to medicine to describe the advancements in the 20th century based on the diagnosis and treatment of disease (the "illness" model) and envision the future focused on disease prevention (the "wellness" model). We expand upon previous S-curve applications in medicine and discuss the obstacles facing the present-day healthcare industry and the numerous advancements that are imminent.

APPLICATION OF THE S-CURVE TO BUSINESS

The practice of strategy development and execution in the business realm uses the principle of the S-curve.[1] A company initially starts with modest growth and subsequently enters a period of rapid growth until it reaches the point of maximum growth.[2] Maturity with shrinking returns (saturated market) then ensues, followed by a plateau and a minimal decline. The crucial component to ensure a flourishing company is to replenish with new ideas, products and finances. Transitioning to a new S-curve is referred to as an inflection point for the company.[3] At this point, there is a discontinuity and overlap of S-curves. The initial plateau of the new S-curve is lower than the previous S-curve which represents a decline in the progression of technology. This "discontinuity" or "chaotic" phase occurs when new technology is in its infancy and is not as good as old technology (Figure 1). However, the new technology subsequently improves exponentially as the new S-curve emerges.

APPLICATION OF THE S-CURVE TO MEDICINE

In 1994, Adler applied the S-curve to medicine and described the theory of S-curve "discontinuity".[4,5]

Prior to the 20th century, the medical field in the U.S. was disorganized with minimal standardized care and quality. With the innovations developed by Abraham Flexnor in U.S. medical schools in the early 20th century, physicians became adept at diagnosing and treating patients who were already afflicted with a disease. The steep section of the "illness" S-curve was marked by antibiotics, vaccinations, anesthesia and surgical and technological advances (Figure 2). The sharp, vertical section of the S-curve plateaued by the end of the 20th century with the advent of high healthcare costs, growing chronic diseases, bureaucracies, unnecessary medical testing, large malpractice claims and abuse of the system by patients and physicians.[5]

Adler predicted the initiation of a second S-curve that is based on "wellness", specifically, health promotion and prevention of disease.[4-6] The "discontinuity" period between the 2 curves is chaotic and represents a decline in healthcare progress. Adler reported that 70% ($700 billion) of the $1 trillion spent on healthcare in the U.S. in 1993 was devoted to preventable disease and that 90% of all patients admitted to acute care hospitals (excluding normal deliveries) had preventable diseases, such as cardiac disease, Type 2 diabetes mellitus and chronic pulmonary disease.[4,5] Despite cost-control methods to decrease health care costs, they continue to escalate in the "discontinuity" period. In addition, fee-for-service reimbursement of physicians to treat diseases offers little incentive to promote a healthy lifestyle through risk factor (smoking, alcohol and substance abuse, stress, poor diet and lack of exercise) reduction for their patients.[5]

APPLICATION OF THE S-CURVE DISCONTINUITY TO PRESENT-DAY HEALTHCARE WITH PREDICTIONS FOR ITS FUTURE

The present work validates and expands upon the theory of S-curve "discontinuity" in medicine described by Adler and offers a perspective of present-day healthcare with predictions for the future. The initial plateau of the "illness" S-curve before the 19th century was primarily focused on keeping the patient comfortable (Figure 2). The robust incline from the early 20th century was due to numerous advances in medicine (antibiotics, vaccinations, imaging capabilities, anesthesia and surgical interventions) designed to diagnose and treat the patient. The drastic increase in healthcare costs and disarray in the the global health care system during the "illness" curve precipitated the plateau due to the depletion in funds, exemplified by growing losses and declining reimbursements. We speculate that the chaotic phase (known as "discontinuity" to Adler) initiated in the late 20th century will extend until the 2020's decade. This tumultuous period as it relates to healthcare delivery has negatively impacted patient care.[7,8] Chronic disease and rising healthcare costs likely play significant roles in triggering
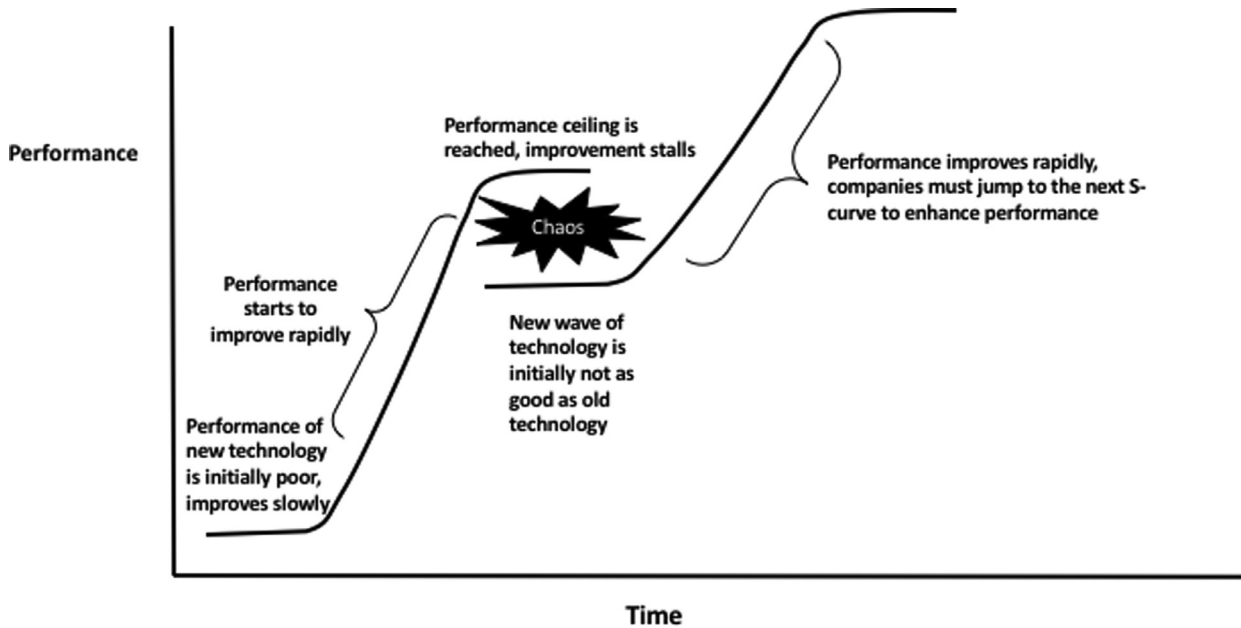
FIGURE 1. Application of the S-curve to business, depicting how innovations start slowly, accelerate and subsequently hit a ceiling. Companies need to jump to a new S-curve to improve performance.

and prolonging the chaotic phase which has been characterized by entry of the electronic health record, the transition from volume to value, alterations in the physician employment model, reimbursement challenges and population health (Figure 2). These factors have resulted in the following sequelae which have negatively impacted healthcare progress as exemplified by physician burnout, nursing shortage and decreasing staffing ratios.

The efforts to combat chronic disease and control rising healthcare costs comprise the current "chaotic" period which will generate the momentum to drive the transition to the next "wellness" S-curve and its predicted dramatic upswing. Other competing initiatives are
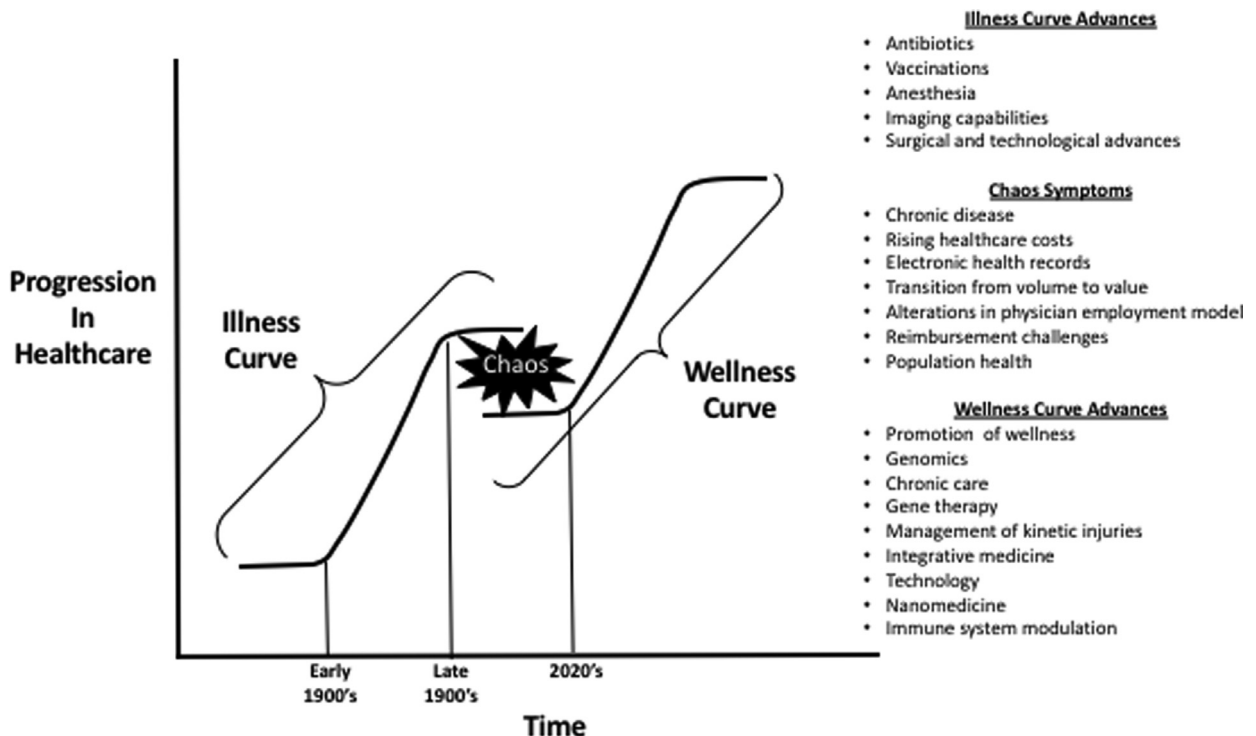

Illness Curve Advances
- Antibiotics
- Vaccinations
- Anesthesia
- Imaging capabilities
- Surgical and technological advances

Chaos Symptoms
- Chronic disease
- Rising healthcare costs
- Electronic health records
- Transition from volume to value
- Alterations in physician employment model
- Reimbursement challenges
- Population health

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

FIGURE 2. Application of the S-curve to medicine, illustrating the "illness", "chaotic" and "wellness" curves.

also born in the "chaotic" period, first of which is volume versus value. Instead of physicians' evaluating as many patients as possible in a single day, there is now an emphasis on value and quality care.[9] In this respect, patients are less likely to be admitted to the hospital or readmitted if recently discharged. Secondly, the employment of physicians has changed from their owning a private practice to now being employed by hospitals. More health systems currently own both the hospitals and the outpatient clinics. This alteration in physician employment encourages a full continuum of care with the goal of maintaining healthy patients without a need for hospital admittance. Insurance companies are now partnering with hospitals and physicians to control costs and manage chronic disease. These modifications in the relationships between physicians and their insurance company and with their patients enhance value-based care and continuity of care. Finally, with the introduction of electronic medical records in the past several years, there is a wealth of medical data for analysis.[10,11] Predictive analytics may be performed on patients' health records which will serve as the impetus for the next S-curve in medicine highlighting "wellness." The "discontinuity" phase represents the overlapping of the 2 S-curves and a shift from 1 curve to the next. The numerous factors described above were the disruptive innovators of the "chaotic" period but will provide the fuel and catalysts to completely transition from the "chaotic" phase to the "wellness" curve.

The Centers for Medicare and Medicaid Services (CMS) reported that the total health care spending for 2016 was approximately $3.4 trillion, up 4.8% from 2015.[12] According to the CMS, U.S. health care spending is projected to reach $5.5 trillion by 2025. Health care spending accounted for 17.8% of the Gross Domestic Product in the U.S. in 2015 and is projected to increase to 19.5% by 2025.[12] The CMS attributes this increase to the aging population in the U.S. and the mounting prices for health care services. The faster growth in 2014 was due to significant coverage expansions under the Affordable Care Act for Medicaid and private health insurance which contributed to an increase in the insured population.[13] The recent shift towards behavioral health highlights the initial plateau of the "wellness" S-curve. More focus is placed on behavioral wellness, providing means to overall wellness and better management of chronic disease. As we enter the "wellness" phase of the next S-curve in the next 5-10 years, people will be healthier and will require less medications and fewer hospital admissions to treat their chronic diseases. This, in turn, will dramatically reduce the amount of money spent on healthcare, allowing the healthcare funds to be reinvested into advancing wellness.

CONCLUSIONS

Each of the S-curve applications described in this report has a limiting factor. The scientific principle imparts "limits to growth" when a population and technology will "hit the wall" in circumstances with depleted fossil resources or water, an economic bubble, or boom and bust.[14] The population of a living organism is limited by the carrying capacity of its environment with increasing environmental resistance.[2] Business is limited by the demand of its market.[2] The limiting factor in medicine is remaining ingrained in the mindset of diagnosing and treating patients. Individuals should be proactive in embracing a healthy lifestyle with an emphasis on prevention of disease instead of succumbing to the morbidity and mortality associated with chronic diseases.

The present "chaotic" phase between the first S-curve in the 20th century and the second S-curve initiating in the next 5-10 years, may seem bleak. People may assume that the costs of healthcare will overwhelm the U.S. economy. By analyzing the scientific S-curve discontinuity theory and applying it to medicine, there is a light at the end of the tunnel. Sense will be brought to the chaos. The same excitement that accompanied the first S-curve in the 20th century will soon be revisited as we jump to the new S-curve with an exponential explosion in the advancement of healthcare based on "wellness". The "wellness" phase will emphasize genomics, healthy lifestyles with potential financial incentives, chronic care, gene therapy, management of kinetic injuries, integrative medicine, nanomedicine and immune system modulation (Figure 2). The black swan theory describes unexpected and rare events that may be considered extreme outliers which have substantial impacts and consequences.[15] Black swan technologic and medical advances such as artificial intelligence and the Human Genome Project will be significant players in the upswing of the "wellness" S-curve.[16] The plateau of the next S-curve will be attained when the population is largely well and disease is being prevented where the patient is willing and the resources are available. The philosophy of medicine has shifted from the "illness" model where the goal was to get sick people well to the future "wellness" model where the objective is to keep people healthy.

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