Applying Systems and Complexity Science to Real Patient Care

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May 26, 2020

Abstract

Abstract Rationale: Our current global healthcare system is not sustainable. It is structured based on the principles of reductionist science which was discovered and developed over the past 400 – 600 years. Because of increasing pace of change and increasing complexity in our world we have increased fragmentation in our healthcare system leading to more harm and waste. Over 100 years ago, the principles of systems, or complexity, science were discovered, first in the discipline of physics. These principles accommodate the constant change and biologic variability in our world. While reductionist principles would be applicable in a static, mechanical world where parts of the system could be isolated, this does not exist in the real biologic world. Method: For the past decade, our abdominal wall hernia team has been applying the principles of systems science to real patient care. Some of the tools we have applied include continuous quality improvement for whole hernia patient processes and non-linear analytical tools to gain insight to improve value-based outcomes. Until we learn to apply and scale these principles across our whole global healthcare system, we will continue to suffer the consequences of our current unsustainable system. Results: We have learned that the application of systems and complexity science to real patient care can lead to lower costs and better outcomes in the context of patients with complex hernia problems. However, these concepts have not yet been adopted in our global healthcare system. Conclusion: Applying the principles of systems and complexity science to our global healthcare system has the potential to lower costs and improve patient outcomes for any patient care process to which it is applied.

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Systems Science for Healthcare

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"Between the healthcare that we have and the healthcare that we could have lies not just a gap, but a chasm"

Crossing the Quality Chasm, 2001 Institute of Medicine

Introduction

Over 20 years ago, two separate groups of astrophysicists discovered something unexpected at about the same time. They found that the expansion of our universe is increasing at an accelerating pace, rather than decelerating as was previously thought. The groups would later share a Nobel Prize based on this discovery.[1]

Although this was unexpected, an increased pace of change in our world has been evident for many centuries. We can see this ever-increasing pace of change in our world through the innovation revolutions that had a major impact on lifespan and quality of our lives, from the Agricultural Revolution that took thousands of years, the Industrial Revolution over a period of hundreds of years and the Information Age that lasted a

few decades. With the global and immediate communication capabilities of the internet, this pace of change will only continue to increase. We are now considered to be in the age of networks.[2]

Fragmentalism – the loss of focus on "what really matters"

With this ever-increasing pace of change, we can see the impact on the reductionist models for our industries and organizations. Fragmantalism has been described as an alternative term for reductionism. As the pace of change and the complexity of our world continues to increase, a reductionist model for an organization will lead to more fragmentation and disconnection. This occurs through the development of more and more department silos leading to poorer communication and more inefficiency and waste as well as almost completely stifling innovation.

To see the negative impact of this increasing pace of change on reductionist designed organizations, we can examine the lifespan of Fortune 500 companies in the United States: the average lifespan was more than 50 years in the 1950s but has decreased to less than 20 years in the 21st century and in 2017 only 60 companies remained in existence from the Fortune 500 list in 1955.[3]

Hospitals and Academic Medical Centers are no different and they may be in the most complex and constantly changing of all organizations in our world. But they have been relatively insulated, with massive subsidies from government, foundations and research dollars as well as philanthropic and investment proceeds. It was only a matter of time before this fragmentation and disconnection would catch up with an unsustainable business model, even in healthcare.

As I learned more about this, I came across graph published by Woolhandler and Himmelstein shown in Figure 1. The graph reveals a many thousand percentage growth of hospital administrators while the growth of physicians has been minimal compare to the growth of administrators.

This fragmentation also leads to systems designed inappropriately into the fragments of care rather than for a patient's entire cycle of care. For example, Electronic Medical Record (EMR) systems are designed for the fragments of care, often with a primary purpose of documentation for the purpose of coding and billing. By only documenting a fragment of care, it is not possible to measure the outcomes of care for any definable, whole patient process. This also prohibits the appropriate data analysis that could be applied to learn how to better measure and improve outcomes.

Ultimately, this increasing pace of change resulting in increased fragmentation and an increase in administrative burden will predictably lead to an unsustainable financial situation. The Commonwealth Fund is one of many organizations that highlight the unsustainable financial situation in healthcare. A graph demonstrating the increase in per capita spending on healthcare for the US and many other countries is shown in Figure 2.

Although it is well-known that the US has the highest per capita spending on healthcare, it is not well-known that the slope of increase of per capita spending on healthcare is nearly the same in every country. We are all on the same unsustainable path- the US is just out in front of every other country.

Applying Systems and Complexity Science to Real Patient Care

For the past decade, our small abdominal wall hernia team has applied the principles of this newer scientific paradigm, systems science, to real patient care. Instead of testing a hypothesis using rigorous prospective randomized clinical trials (PRCTs), we collect data from real patient care, periodically analyze the data which provides feedback loops to allow the clinical team to gain insight into the factors and combinations of factors that are most correlated with good and bad outcomes.

This can then lead to ideas to improve how we measure factors and outcomes and generate new ideas to improve outcomes. The tools from a systems science paradigm include principles of continuous quality improvement (CQI) and non-linear analytics.

The reductionist paradigm relies on linear statistics to try to prove a cause and effect relationship between a factor (drug, device, etc.) and an outcome measure by attempting to isolate them from all other factors and outcome measures. In systems science, the analysis and feedback tools are meant for learning and improving whatever is measured in the real world of patient care.

Using the Wrong Tools in Health Research

'Although it is inappropriate, and potentially inaccurate, researchers frequently use linear regression on nonlinear phenomena, calculus on discontinuous functions, or $\chi 2$ when data points are interdependent.'— *Eric Dent PhD, 1999*

The principles of systems science are clear: We're using research tools designed for static, isolated, linear and mechanical systems, but human beings are nonlinear, adaptive, biologic and heavily influenced by interactions with the rest of our constantly changing world.

In his book "Predictive Analytics: The Power to Predict Who Will Click, Buy, Lie or Die," Eric Siegel describes the story of IBM Watson's victory in the game Jeopardy against its two greatest human champions at the time.[4] He said it is one of the best examples of machine learning and the potential for wonderful benefits if applied appropriately to health care. But he is clear in the need for an accurate context that produces the data and the need for multiple collaborations to share what is learned from the data.

In health care, we have a very poor understanding of the context that produces the data available that we see in fragmented care, often primarily from coding and billing data. This data is incredibly inaccurate. Some estimate that nearly 50% of billing data is wrong or omitted, with the great majority from human and systems error, not fraud.[5]

But when the application of the principles of systems science is done well, and Siegel gives many examples in his book, then the use of a well-defined context and meaningful collaboration can prevent the law of diminishing returns, or as Siegel calls it in his book, "overlearning," which can allow for continuous improvement of value over time.

Applying Data and Systems Science to Clinical Care

Starting in 2011, our small hernia team began to learn how to apply systems science principles to real patient care. It was not an easy process- we didn't have a roadmap or textbook. We were trying to take the principles of a scientific paradigm that had been used in other industries- financial industry, baseball (known as Moneyball), etc. and apply it to real patient care.

One issue was that unfortunately, the application of systems science in other industries was used to improve the revenue and profit of the organization and/or win against other competitors. It was not being used to improve the value for the customers as we were attempting to do. So, we had a lot of trial and error.

At first, we were measuring way too many data points. We spent too much time and resources on trying to capture data, and not nearly enough time and resources figuring out how to measure outcomes in terms of value or put in Einstein's words: *Measure what Matters* . We then had to learn how to apply analytical tools and feedback loops to improve value. Improved patient outcomes and lower costs began to happen quicker. The hospital noticed because they were no longer losing money on our complex hernia patients.[6] They even began to make a modest profit on each patient.

Turning Data into Knowledge – The Sense-Making Process

Our most unexpected and important discovery came a few years after we started, and it took another few years to mature our understanding of the impact of our finding and learn what process improvement measures we could implement to address the discovery.

One day, we were having one of our hernia team CQI meetings and we were looking at the patients who had complications and less than ideal outcomes. We looked at our operative techniques and the typical patient factors like BMI and smoking, but nothing seemed to explain a pattern for these patients who had bad outcomes. Then our patient care manager spoke up and noted that the patients that had bad outcomes seemed to be the same patients that were more challenging to deal with before surgery.

She described patterns in these patients- some were angry, some had unrealistic expectations (especially those expecting a "quick fix"), some had high anxiety and/or controlling personalities. We did not yet know how to measure this, but we thought that this might be a pattern. We needed some sort of measurement tool. Lacking much expertise in this area at the time, we settled on a subjective measure we called "emotional complexity" and we put patients in categories of either high, medium or low.

As the next 6-9 months went by, we recorded emotional complexity along with a few dozen other data points. The next analysis of the data we ran showed that the emotional complexity was the highest modifiable factor predicting outcomes for our patients. The only factors with a higher correlation to outcomes were the size of the hernia and the number of prior hernia recurrences, neither of which could be modified.

Since we found that this was such an important factor, we invited a small group of social science and social worker experts to our next CQI meeting to develop a more robust measurement tool.[7]These findings came from principles of systems science using a variety of analytical tools. As we learned about the impact of a patient's neuro-cognitive/emotional state on surgical outcomes from the analysis of data in our own patients, we found that this is not that surprising based on recent research in neuroscience and the neurophysiologic impact that traumatic events can have on the brain. We indeed observed that many of our patients suffered from traumatic events in our healthcare system. This insight lead to pre-surgical evaluation of neuro-cognitive/emotional issues and implementation of cognitive behavioral therapy as part of a prehabilitation program for most patients. The concepts of applying a CQI process to real patient care are illustrated in Figure 3.

Understanding Pattern Formation in Clinical Care – who will benefit, who will be harmed, and for whom does treatment represent waste?

For essentially every test and treatment we have in health care, there are basically three subpopulations of patients who undergo a test or receive a treatment. First, there is a group that benefits from the test or treatment, but there is also a group that does not benefit (this is waste in our system), and finally, there is a group of people who are harmed as a result of that test or treatment.

Until now, our simplistic thinking has allowed us to rationalize that the waste and harm was just a necessary evil to help those patients who benefit from a test or treatment. Who could argue that e.g. a few unnecessary mammograms/PSA tests/screening tests for hypertension or diabetes are justified to save a patient's life? But systems science principles argue, and the data from many decades of screening have shown, that it is not so simple, and we are perpetrating a degree of waste and harm in patient care that is not sustainable and not ethical (the problem has now received Cochrane recognition with the formation of the "sustainable healthcare" group - https://sustainablehealthcare.cochrane.org/).

To understand how to define the subpopulations that are harmed and those who do not benefit (waste), a more complete understanding of systems science and data analysis is required. The ultimate goal of systems

science is to improve outcomes that measure the value of care for any definable, whole patient process. This is achieved by discovering the patient factors and treatment factors that most impact outcomes that measure value and applying insight from the analysis of data to improve these outcomes.

Over time, the analysis of data can produce algorithms to identify these subpopulations. With insight from multiple feedback loops, the clinical team can implement ideas for improvement which can result in lowered costs while outcomes are improved over time. For example, when enough data is accumulated and analyzed appropriately, a subpopulation can be identified who would likely be harmed and another subpopulation that would have no benefit from screening or interventions.

At the same time, another subpopulation of people could be identified who would benefit, some of whom would not otherwise be receiving a test or treatment. With these subpopulations better identified, the costs for disease screening and treatment could plummet while other quality measures would improve, resulting in better value for patients and the system-as-a-whole.

Conclusions

In the past decade, I've seen a growing awareness about *systems and complexity thinking* and the development of "user-friendly" systems science tools. But I've also noticed a strong bias toward the reductionist science tools as "real" or rigorous science. Although many people in healthcare are now recognizing systems science concepts, they tend to treat it as a soft science, not as valuable or valid as a rigorous prospective RCTs. However, the systems science paradigm provides a much more complete description of how our world really functions and so the tools are much more valuable to apply for true learning and improvement in healthcare.

The tools of systems science such as CQI, non-linear analytics and team-based patient care coordination and management have the potential to focus on the goal of improving the value of care for our patients. That also will improve the value for all the parts of our system that contribute to that value and reduce harm and waste. This will take effort at the level of each local environment and in the context of each definable patient care process.

We are going through a paradigm shift in the scientific understanding of our world, from the machine as a metaphor for human beings to an understanding that we are complex, adaptive and dynamic systems – imperfect and nonlinear, but able to adapt in many various ways. We can't change the fact that the pace of change and complexity in our world, like the expansion of our universe, is increasing at an accelerating rate. But we can learn to apply the science of systems so that we can learn to improve the value care for patients and our system-as-a-whole. This will allow us to transform our global healthcare system to one that is sustainable, and I believe this can lead to a better world.

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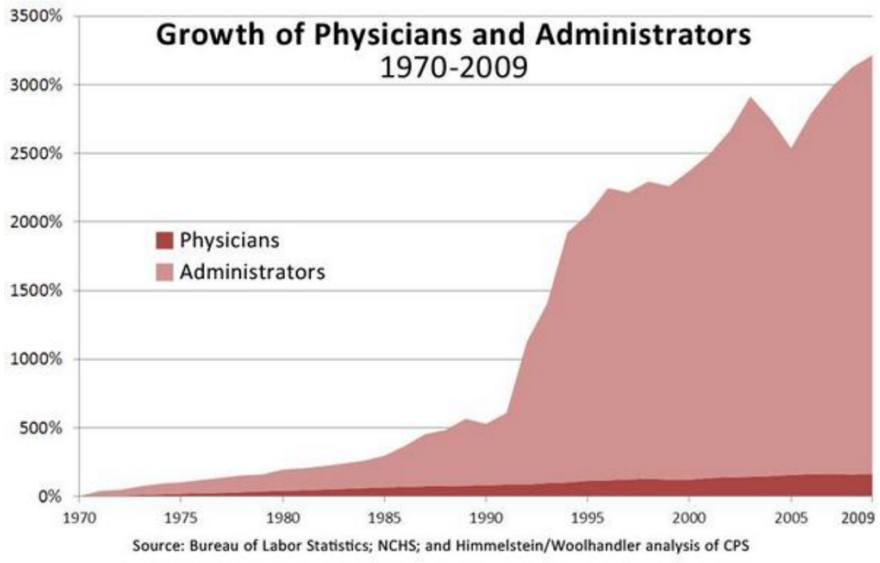

Fig 1 – Growth of Physicians and Administrators (Source: Bureau of Labor Statistics; NCHS).

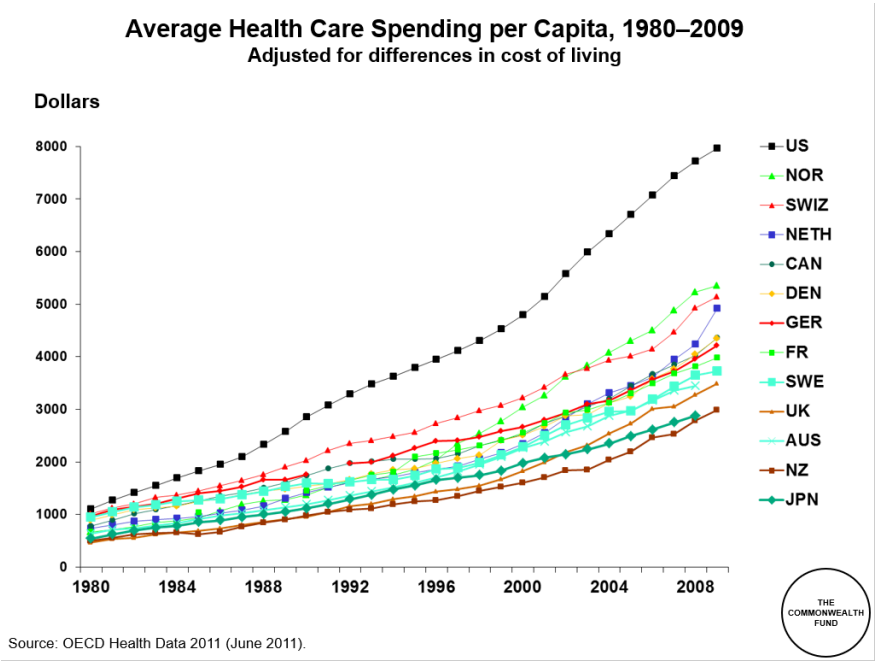

Fig 2 – Growth in healthcare spending per capita in various countries since 1980 (source: Commonwealth Fund).

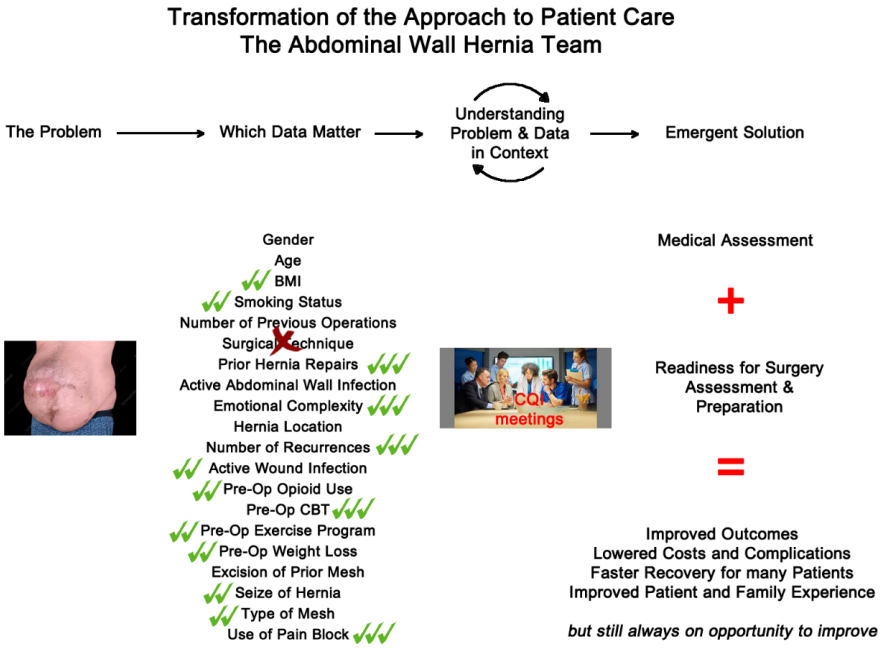

Fig 3 -Applying the principles of clinical quality improvement to improve value of care and reduce harm and waste.

Acknowledgements: Joachim Sturmberg for providing ideas and extensive editing of drafts including the development of Figure 1. Brandie Forman and Michelle Preston for providing patient care management and significant contributions in the CQI effort. Sheila Grant, Dave Grant, Ron Eaglin, Karla Moore and Briana Alvoid-Preston for contributing engineering, data science and business intelligence expertise to the CQI effort.