World Medical and Health Policy

The Physics of Health Care: Viewing the U.S. Health-Care "System" from the Perspective of Quantum Mechanics

Amy Kislyakov and Rick Mayes

Leading explanations for high per capita and total health-care spending in the United States tend to point to high health-care prices as the primary culprit, which are a major contributor. Yet prices and spending do not exist in siloed vacuums. They are inherently part of, and deeply intertwined with, patient and clinician interactions, administrative norms and requirements, organizational structures, and socio-cultural systems of medicine. Consequently, what is often thought of as a bounded health-care "system"—centered primarily around the volume and price of health care—may, in fact, be unbounded, spilling over and interacting with other seemingly unrelated domains. Adding to the scholarly work already addressing this issue, we aim to provide a new lens that captures (if only partially) the exquisitely complex and hidden equilibrium present in what constitutes U.S. health care. Quantum and relativistic physics, with its focus on non-deterministic reasoning, can serve as a helpful framework for understanding the moving parts of health care—their interposition as well as their interdependence. Using this analytic lens could potentially lead to new interventions (involving clinicians, patients, and payers) that concurrently target problems at multiple points in the system.

KEY WORDS: health policy, health systems analysis, physics

Introduction

According to physics theory, perfect efficiency—defined as the full translation of energy inputs into outputs—is impossible to achieve (Walker, 2017). One might understand this as a law of nature, separate from the tangible observations of the world around us. Yet this law seems to hold true in multiple areas, including U.S. health care.

In a 2018 comparative analysis of international health-care expenditures, researchers found that the United States spent approximately twice as much per capita as other high-income countries on health care. This extra spending, however, did not achieve better health outcomes; with some outcomes, such as life expectancy and maternal mortality, being worse (Papanicolas, Woskie, & Jha, 2018). U.S. social expenditures and health-care utilization were found to be relatively similar to other high-income countries, which meant that the volume of health care provided only explains a (relatively small) part of U.S. exceptionalism (Papanicolas et al., 2018). The data suggest that—in addition to disparities in health insurance coverage—the main driving factors for the United States's unrivaled level of per capita health-care spending are the high price of: physician and hospital

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services, pharmaceuticals, and diagnostic tests: "It's the prices, stupid: why the United States is so different from other countries" (Anderson, Hussey, & Petrosyan, 2019; Anderson, Reinhardt, Hussey, & Petrosyan, 2003).

While prices are a major driver of high health-care expenditures in the United States, excessive health-care spending remains a complicated phenomenon that reflects complex systemic and contextual factors that influence the reality of high prices (Rosenbaum, 2017). Trying to pinpoint and explain a supposed cause for each factor would be similar to attempting to find the origin of a spider web. It is impossible. Everything seems to be intricately connected, such that answering the question of "why" will not have one answer and will require an understanding of the systemic context.

Our intent, therefore, is not to use physics as a form of evidence or oversimplified analogy (shoving some large uncontainable thing into some other known theoretical, cognitive, or conceptual structure). Rather, our goal is to turn the analytical problem of explaining excessive health-care expenditures in the United States on its head by taking something complex (U.S. health care) and overlaying it onto something even more complex (quantum mechanics) (Eastwood, 2016). In short, instead of stuffing the concept of health care into some other bounded structure, we are attempting to break down the bounds of the structure altogether.

On a global scale, we hope that this lens of physics might subvert linguistic, political, and cultural barriers by pulling from a field of knowledge where concepts —rooted in the universal language of mathematics—tend to hold a standard and agreed upon meaning. Even so, while issues of health-care access, quality, and cost are universal, we acknowledge the limitations of this theoretical lens, as the specific analogies we will highlight come from U.S. health care.

Ultimately, high health-care spending and high health-care prices may be partly the same phenomena caught in a feedback loop—both causes and products of other factors that make up health-care finance, organization, and delivery in the United States. For example, high health-care prices could be as much a product of both the fragmentation and unmatched administrative inefficiency of U.S. health care as they are a contributor to high total health-care spending (Gerber & Skinner, 2008). If so, health-care spending and outcomes are deeply entangled and interconnected, similar to that of the quantum world. Understanding this reality is critical for possible reform interventions, as excessive spending on medical care in the United States has actualized in the form of increased health and economic disparities: "fewer people covered by private insurance, the rationing of care in public health programs, and the lack of funds for other social programs. These distribution issues, coupled with the large waste, imply that efforts to address medical spending need to be among our highest priorities" (Emanuel, 2018).

In this commentary, we aim to add to previous findings of health policy scholars that address the limitations in some of the deterministic reasoning associated with health economics and to introduce new possible modes of thinking about high U.S. health-care prices and excessive total health-care spending. Our contribution is a simplified way of re-perceiving the problems of health care in a new light through the lens of quantum and relativistic physics.

The Bohr Model and Social Mobility for Lower Health Spending

In 1913, Neil Bohr postulated that electrons orbit the nucleus in the same way that planets orbit the sun and he proposed that the electrons are restricted to special orbits around an atom's nucleus (Bohr, 1913). They might be able to jump between orbits, but only if they acquire a certain amount of energy. Electrons closer to the nucleus—and hence on a lower orbit level—feel a much stronger attractive force and, thus, require much more energy to be removed (Walker, 2017).

The electron orbits, in this case, are representative of an individual's particular socioeconomic status and the electrons are symbolic of the individuals. The previously mentioned cross-cultural analysis emphasized that U.S. social spending was similar to other countries, implying that the differences in population health outcomes were likely not associated with the socioeconomic conditions of the respective countries (Papanicolas et al., 2018). This assumption, however, does not account for the significant differences in the orbits of each country and the mobility that each person needs in order to jump from a lower orbit to a higher orbit. The U.S. is less socioeconomically mobile than comparable nations and has far less mobility than the general public assumes. This lack of socioeconomic mobility contributes to overall health-care expenditures because of the lower orbit's higher rate of chronic disease, disability, and premature death (Chetty et al., 2016).

So how might we increase social mobility for better population health and lower health expenditures? How might we provide the needed energy to traverse these energy barriers?

The Photoelectric Effect and Improving Public Health

The photoelectric effect is representative of the finding that shining light on certain materials can eject electrons from that material (Wong et al., 2011). The minimum amount of energy necessary to eject electrons from a particular material is referred to as the work function. To eject electrons, the incident beam must have a frequency greater than a certain minimum value, referred to as the cutoff frequency, f_o. If the frequency of the light is less than f_o, then it will not eject electrons, *no matter how intense the beam is* (Walker, 2017).

The frequency, in this case, is representative of the approach that the country needs to take in order to help those in disadvantaged populations. The intensity is depictive of the dimension of energy that we typically use in order to accomplish this, that being money. Does money have the potential to provide the energy that those in the lowest orbit need in order to achieve better access to medical care and improved personal health? Cross-sectional studies have shown evidence of major improvements in the lives of low-income adults who were given resources and medical coverage, with improved mental health, better self-reported physical health, and reduced risk of medical debt (Mazurenko, Balio, Agarwal, Carroll, & Menachemi, 2018). Other studies, however, did not detect a statistically significant improvement in blood pressure, cholesterol, or diabetes control during an

18-month follow-up period after access to health-care services was increased in an individual case of Medicaid expansion in Oregon (Baicker et al., 2013).

Spending more money to expand health insurance, therefore, may not be sufficient to significantly improve populations with higher health-care needs no matter how large the expansion (Levy & Meltzer, 2008). Perhaps there are more complex interplays among race, gender, and socioeconomic status (Williams, Priest, & Anderson, 2016) that require approaches to improving population health that use a different frequency than just increasing the "intensity" (coverage) of health insurance.

The Pauli Exclusion Principle and Universal Coverage

The Pauli Exclusion Principle states that only one electron at a time may have a particular set of quantum numbers (Pauli, 1946). In other words, we are all unique, each with our own background, preferences, and ways of thinking.

One might wonder, then, if people in low orbits are disproportionately contributing to health-care spending—as a result of increased disease prevalence and poor coverage—why don't we have universal health care? Perhaps it has to do with the unique political culture of the United States that emphasizes individualism and strives for limited government involvement. This culture makes it very challenging to enact health-care policies that both work and succeed in the eyes of the public (Oberlander, 2012). For example, the Affordable Care Act (ACA) increased the number of people with insurance coverage by approximately 20 million people (Obama, 2016), but it has struggled with cost control due in part to the ambiguity surrounding what this regulation would mean to each person or stakeholder (Weiner, Marks, & Pauly, 2017). The essence of the problem is the fact that while the general public and government want the cost curve bent with regard to overall health-care spending, individual patients, their care-providers, and loved ones want to receive as much value in health care as possible, regardless of the cost (Porter, 2010).

Ultimately, health is a private affair that emphasizes patient autonomy, but this privacy may be playing a significant role in increasing health spending in the United States. If prices are to be controlled, in order to try to restrain the growth in total health-care costs, there has to be a balance between individual needs and the needs of the country. That might mean sacrifice; personal losses; disadvantages; and, most importantly, an acknowledgment of limits, constraints, and necessary trade-offs in health care (Pauly, 2011).

Heisenberg's Uncertainty Principle and the Lack of a Constant in U.S. Health Care

Heisenberg's Uncertainty Principle states that if we know the position of a particle with greater precision, its momentum is more uncertain; if we know the momentum of a particle with greater precision, its position is more uncertain. The same applies to the complementary relationship of energy and time (Walker, 2017). In other words, we are surrounded by trade-offs, most of which are unavoidable

laws of nature. Similarly, health care can be defined by unavoidable trade-offs (Williams et al., 2016).

The cross-cultural *Journal of the American Medical Association (JAMA)* study mentioned earlier emphasized the fact that, of all the countries, the United States is the only one to have a voluntary, private employer-based and individual-based system (Papanicolas et al., 2018). This result, in and of itself, is the product of a long history of professional, economic, and political trade-offs (Morone, 2010). In the development of Medicare and Medicaid, the initial hope was to achieve national health care. However, due to formidable interest-group opposition, supporters concluded that they would have to pursue more modest goals. They targeted incremental expansions of coverage with health insurance for elderly Americans, resulting in the passing of Medicare for the elderly and Medicaid for the poor (Blumenthal, Davis, & Guterman, 2015a). Since then, most health policy has focused on restraining cost growth without reducing quality (Blumenthal, Davis, & Guterman, 2015b).

Here is where the trade-off problem lies. The Heisenberg Uncertainty Principle asserts a fundamental limit to the complementary relationship of two variables, in that $x \times y \geq$ fixed number (Walker, 2017). In other words, the precision with which we know the momentum of a particle decreases as the precision of the position increases *because* the two variables equal a constant. But the problem in health care —and especially with regard to the inherent trade-offs involved—is that we do not have a publicly agreed upon constant that asserts a specific limit (Eastwood, 2017). Part of the reason we have no constant is due to the way most doctors are paid—on a fee-for-service basis. In this system, doctors do not receive an hourly rate or a set annual salary. Instead, they are paid primarily on the number of patient visits, diagnostic tests, and clinical procedures they provide. As a result, we end up with a fragmented system (Schroeder & Frist, 2013), in which quality is not proportionally going up with price and trade-offs are almost impossible to control or predict (Robinson, 2001).

Quantum Entanglement and the Social and Cultural Contexts of Health Care

Quantum entanglement is a physical phenomenon which occurs when pairs or groups of particles are generated or interact in ways such that the quantum state of each particle cannot be described independently of the state of the other(s), even when the particles are separated by a large distance—instead, a quantum state must be described for the system as a whole (Walker, 2017). In other words, while the health-care system must incorporate, and respect, individuals and separate groups, ultimately, each individual component is, and must act as, part of a larger whole.

Oftentimes, the characteristics of the whole seem to be reflective of the culture. The *JAMA* study referenced previously mentioned that while the number of specialist practitioners in the United States, both as an absolute number and percentage, was not considerably different from comparison countries, the salaries paid to both generalists and specialist physicians were markedly higher in the United States. It is tempting to see this as a result of the fee-for-service system,

where doctors are paid more when they utilize more services; however, the study indicated that health-care utilization was relatively comparable among all countries (Papanicolas et al., 2018). Therefore, higher total health spending might be partly a function of physician expectations, which ultimately derive from the culture in which physicians function.

To understand the context of this problem, one has to look more closely at medical education and the subsequent formation of a medical culture with higher financial expectations. Average medical school debt is now closer to $200,000 per student (up from $32,000 in 1986), leaving doctors responsible for paying off their debt for years after they finish their education (Grischkan et al., 2017). This leads to a culture of expectation (or financial necessity), in which doctors are unwilling to negotiate their salaries for fear that what they have invested will not equal their return. In addition, the high cost of medical school leads to a failure to achieve greater inclusion of minority students in medical education, who are more than twice as likely as other students to express a desire to serve underserved communities (Ansell & McDonald, 2015). This failure of diversity among medical providers has consequences on the outcome of racial minorities, as it was found that for almost every disease studied, black Americans received less effective care than white Americans, and these disparities persisted despite matching for socioeconomic and insurance status (Ansell & McDonald, 2015).

Wave-Particle Duality and the Tribalism of Health Categories

Wave-particle duality is reflective of the fact that light can sometimes behave as a particle, and vice versa (Walker, 2017). To try to force light and electrons into categories like waves and particles is to miss the essence of their existence—they are neither one nor the other (they have characteristics of both).

There seems to be a basic human need to identify with and assign others to categories, whether that be "sick" versus "nonsick," "Republican" versus "Democrat," or "us" versus "them." In doing so, however, we may overlook the commonalties and miss the essence of our existence. We also miss the fact that we grow, age, and will eventually fall into many categories over the course of our lifetime. For example, the ACA's individual mandate—a requirement that nearly all Americans purchase health insurance—remains one of the most disliked parts of the Act; approximately 70 percent of Americans oppose it because they believe it is unfair for healthy people to have to pay for sick people (Gordon, Gray, Hollingsworth, Shapiro, & Dalen, 2017). Gawande (2017) describes this as two sets of values in tension: "we want to reward work, ingenuity, self-reliance. And we want to protect the weak and the vulnerable—not least because, over time, we all become the weak and the vulnerable, unable to get by without the help of others." But because we don't have an overarching perspective that allows us to see beyond the limits of time, we aren't able to sufficiently empathize with the people we are paying for *until* we get a diagnosis that puts us in the "sick" category (Conrad & Barker, 2010).

It's not that categorizations are bad; in fact, they are a necessary part of science and life. But categorizations can be dangerous if we don't recognize the line that we

tend to draw between ourselves and others. As Gawande (2017) explains, "our political debates seem to focus on what rules should be for our place in line" or, in other words, our personal category, but "the mistake is accepting the line, and its dismal conception of life as a zero-sum proposition. It gives up on the more encompassing possibilities of shared belonging, mutual loyalty, and collective gains."

Einstein's Theory of Relativity and Perspective in Health Care

In physics, every time you measure an object's velocity or its momentum or how it experiences time, it is always in relation to something else (Walker, 2017). Sometimes these relations are so powerful that they hinder our attempts at health-care reform.

For example, one proposed solution for our health-care expenditure problem is to use Medicare reimbursement rates for all payers. While this does seem like a viable solution, the problem would be the sudden loss of income would bankrupt numerous hospitals and physician practices. In other words, it's not that this policy could not be instituted, but it seems unlikely that such a proposition would be successful if done in a manner that would highlight the relationship between what we have now and what we had before (Anderson & Herring, 2015).

In a larger context, this tendency to understand our situation from a relative frame of reference may make it easier to understand why our health-care prices are very high. The 2018 *JAMA* article concluded that high U.S. health-care expenditures ultimately derive from high prices (Papanicolas et al., 2018). But what if it is the other way around (Aaron & Ginsburg 2009)? What if high health-care spending is leading to higher prices by proxy of the demand? Maybe prescription drug prices are higher in the United States than in the rest of the industrialized world in part because—unlike in every other advanced nation—manufacturers are allowed to set their own price for a given product (Kesselheim, Avorn, & Sarpatwari, 2016). Manufacturers set prices based largely on the current observable relations. In short, if they see that health-care spending is high, it can lead to the assumption that high drug prices are feasible or even "normal" (Robinson, 2001).

Black Holes and an Unlimited Demand for Health Care

A black hole is a region of space in which the gravitational field is so powerful that nothing, not even visible light, can escape its pull—a kind of bottomless pit in space-time that will suck in anything around it (Walker, 2017).

This might serve as a somewhat grim analogy to health care in the United States, a sector which also seems to consume huge amounts of resources. Yet it does hold true in some aspects. For example, with the creation of Medicare and the subsequent reduction of financial barriers to medical care, the use of services by the elderly increased immediately and significantly (Mayes & Berenson, 2006). Similarly, the ACA reduced the costs of medical care to millions of individuals, allowing for much greater accessibility and subsequent consummation of resources,

but it didn't reduce or even restrain the annual growth rate of national health expenditures that are estimated to reach approximately 20 percent of GDP in the next decade (Cuckler et al., 2018).

It's not just the fact that these health-care resources are easily accessible. There is also the gravitational force that is responsible for pulling these resources in. Gawande (2015) admits, "as a doctor, I am far more concerned with doing too little than doing too much." Patients contribute to the gravitational force as well. Rosenbaum (2014) explains that, as patients, "when we fear something wrong, we are far more sensitive to the mere possibility of its occurrence rather than its actual probability." Therefore, when diagnostic tests and other medical resources are available at low or no cost to the patient—even if they are of no actual benefit—patients will take them regardless of their financial toll on the health-care system through increased spending. This phenomenon is often referred to as "moral hazard" (Finkelstein, 2014).

Conclusion

The tendency to lose oneself in specific stimuli at the cost of not seeing other things that are right before one's eyes is called "inattentional blindness." In other words, it is learned blindness. It may not be one that we consciously choose, but it is one that has consequences for both the individual and the collective (Rosenbaum, 2013). With regard to health care, focusing exclusively on just one part of the system (physician behavior) or on one isolated goal (reducing hospital readmissions)—without taking into account the other stakeholders (patients) and interactive context involved—has resulted in unfairly villainizing physicians as greedy for financial gain when the greed is "more often a hunger for information" (Rosenbaum, 2017), increased (avoidable) mortality (Fonarow, 2018), and a failure to recognize that "effective interventions may need to occur concurrently at multiple points in the system and involve both clinicians and patients" (Oren, Kebebew, & Ioannidis, 2019). This "inattentional blindness," however, does not have to be permanent. We just need the right tools to help us see more clearly.

If we want to achieve the Quadruple Aim in health care (reduce the per capita cost of health care, improve the patient experience and quality of care, improve overall public health, and improve the work life of health-care providers) (Bodenheimer & Sinsky, 2014), then we are going to have to take a multifaceted approach (Glickman, Di Magno, & Emanuel, 2019), one that acknowledges the many layers and variables involved. It starts with an understanding of the orbitals and how one's socioeconomic status is associated with chronic disease prevalence, which contributes to personal and collective health expenditure as a consequence of the bidirectional, and paradoxical, relationship between environmental stresses and poor insurance coverage.

To see things as they truly are, we also need a shared baseline or point of comparison. We need a common goal that will serve as something to collectively strive toward or, perhaps, away from. Without these commonalties, we end up with black holes—gaps in the system that continuously suck in our resources while

failing to produce the outcomes we desire. We attempt to pinpoint the source of this problem, the black hole, and we don't see anything because it is (literally and figuratively) invisible. Prices and spending in health care may be one and the same. Saying that one causes the other may be the equivalent to saying that the black hole causes the black hole. Instead, we need to look at the whole galaxy of health care. In understanding the relationship between these black holes and the surrounding planets, we are able to get a more realistic picture, one that depicts the health-care system as an ever changing and fluid landscape where, essentially, we all revolve around one another, all part of the same gravitational wave, all moving in the same direction, even if we don't realize it.

Amy Kislyakov, BA, is a graduate of the University of Virginia (UVA) and currently a graduate student in anthropology at UVA.
Rick Mayes, PhD, is a professor of public policy and co-chair of the Healthcare Studies program at the University of Richmond, as well as a professor at the University of Virginia School of Nursing.

Notes

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Corresponding author: Rick Mayes, bmayes@richmond.edu.

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