Truly, Broadly, and Deeply: How Dynamic Visualizations Are Changing the Way We Understand and Communicate HEOR Findings

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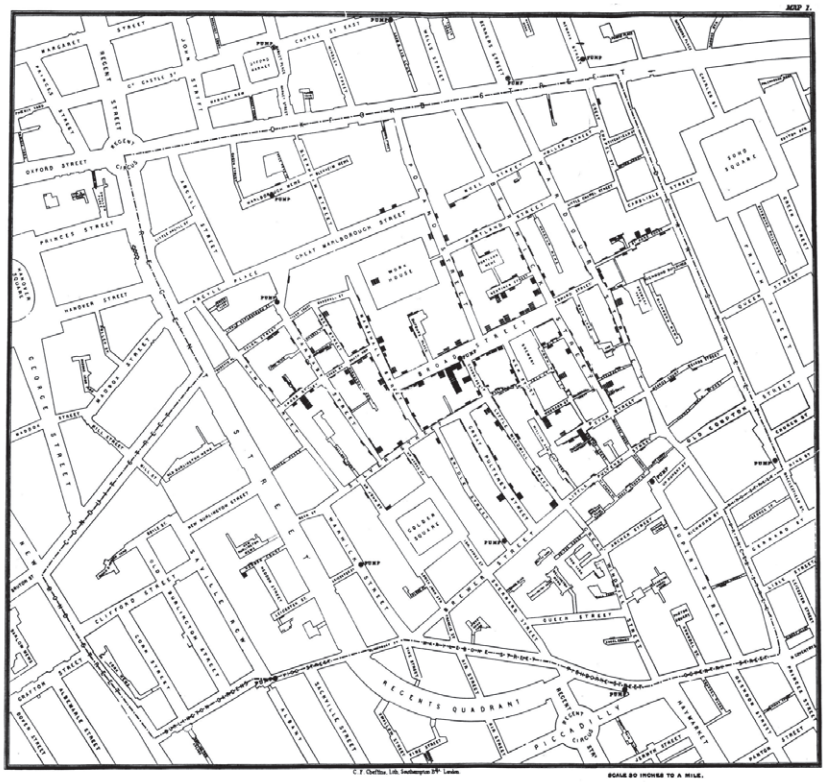
Effective graphical data visualization enables the brain to digest complex ideas more comprehensively; which has enormous potential for communicating findings using big, complicated, or highly idiosyncratic data.

Traditionally, data presented statically—like numbers in tables—have been the norm in the fields of epidemiology, health outcomes, and pharmacoeconomics. However, the science of data visualization is changing that. At first glance, displaying data in a manner that is dynamic and interactive might seem like a gimmick, something to "dumb down" and "pretty up" information for less technical audiences, but the reality is far more complex (and important). Visual patterns and displays can convey data, meaning, and effects far more effectively than language, and people can digest complex ideas far more easily in a visual format. Pharmacoeconomics is a data-heavy field, where findings need to be communicated fairly and accurately to audiences of clinicians, the general public, and policy and decision makers. Data visualization methods—which have been used extensively in a number of other fields but have not been widely taken up yet in health economics and outcomes research (HEOR)—can support these communication and decision-making processes.

At the ISPOR's 2018 annual meeting in Baltimore, the authors presented a workshop on potential applications of data visualization in HEOR. For many of the attendees, visual translation of data has become a client expectation and participants in the workshop were interested in how to deliver on that. But while the participants at the workshop were cognizant of the availability of off-the-shelf software tools for presenting data visually, many had yet to see the technology used to present complex HEOR and epidemiology data in a more dynamic manner. ›

Figure 1. John Snow's cholera map (note, this image is in the public domain)[11]



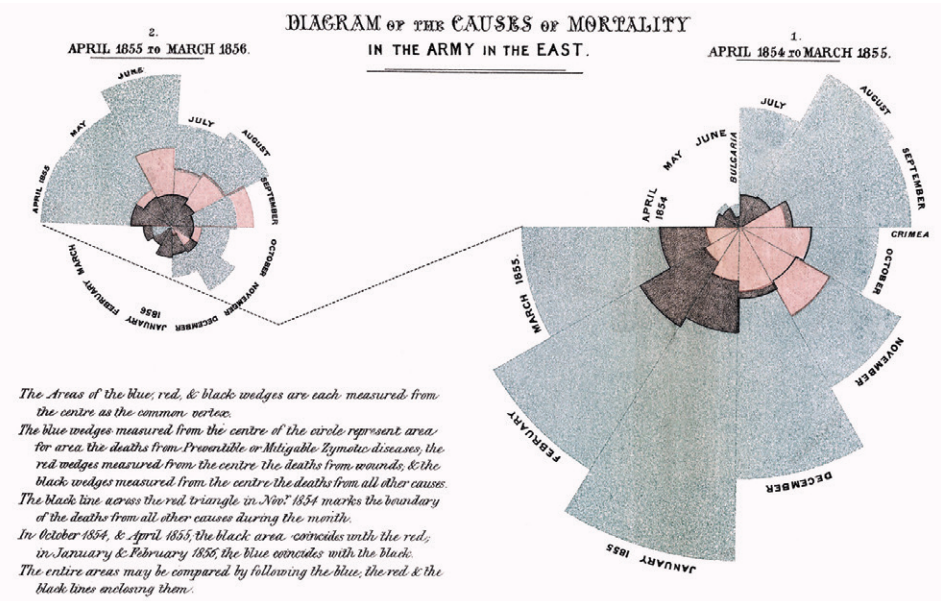
VISUALS IN HEALTH INFORMATION COMMUNICATION ARE NOT NEW

Static data visualization has had a surprisingly long and occasionally vital role in the communication of health information, particularly for informing nontechnical audiences. One of the most famous examples is John Snow's cholera map from London in the 1850s (Figure 1). The map provided a critical understanding of the relationship between the source of infection—a water pump on Broad Street—and the distribution of cholera cases. Black is used to indicate the presence of cholera at an individual address and the length of the mark, the number of cases. Position illustrates the geographic spread of the disease, but also provides insight into where there was a lack of disease. The map helped facilitate public health reforms to stop the spread of infection and the development of infrastructure to avoid future outbreaks, because it was able to simply communicate the evidence on the source of disease to a broad audience.

Florence Nightingale's Coxcomb charts (Figure 2) are another example where information presented graphically achieved change where words and text had failed by influencing decision makers to effect public health reform. As a nurse tending to the wounded during the Crimean war, Nightingale saw the impact of poor sanitation in hospitals. However, she struggled to make officials understand that deficiencies in hygiene were killing more solders than actual battles. Realizing that images would tell a more powerful story than numbers alone, she created the Coxcomb charts to illustrate how avoidable or treatable conditions were responsible for more deaths than battle wounds. In the image, the small red and black segments at the circle's center indicate deaths due to battle wounds and the large gray areas, deaths due to other causes. The position around the circle represents the month and the size of the segment, the number of deaths. These diagrams enabled Florence Nightingale to illustrate the magnitude of the problem to decision makers and as a result, her campaign for improving hospital conditions was taken more seriously.

Snow and Nightingale used their static data visualizations successfully to provide critical evidence that led to government healthcare reform. What is common to both visualizations is that they clearly and effectively tell a compelling story, with each element of the image—color, shape, and space—communicating a particular aspect. These tenets of visual storytelling, the economical use of visual elements to synthesize a vast amount of complex information, have been retained as data visualization has evolved. What is new is the added element of interactivity.

Figure 2. Florence Nightingale's Coxcomb diagrams (note this image is in the public domain)[12]



INTERACTIVITY ADDS A NEW DIMENSION

Interactivity in visualizations allows for the incorporation of even more layers of data and the communication of more complex concepts. There are excellent examples of the use of interactive visualizations to explore and explain changing demographics and health statistics from a global perspective—the World Health Organization and Gapminder are 2 organizations that provide well-designed online tools for these.[1,2] However, these types of tools are only now starting to be developed in HEOR. As part of the workshop, examples were presented of the use of interactive data visualizations to display the findings of pharmacoeconomic, patient-reported outcomes, and network meta-analysis studies; these are discussed in more detail below.

The first visualization was of a cost-effectiveness model created on behalf of the Canadian Pharmacists Association demonstrating the benefits of pharmacist prescribing in hypertension care.[3] This model is a modern example of the role for data visualization in advocacy—taking complex data, with results that can have a real public health impact and presenting them in a way that is accessible to a wide range of audiences. Hypertension is a leading cause of premature morbidity and mortality worldwide, and the magnitude of the problem is worsening.[4-6] The results of several randomized controlled trials have identified that involving community pharmacists in care improves outcomes among patients with hypertension, presumably by lowering barriers for optimal medication titration and monitoring.[7,8] What has been less clear is the cost-effectiveness of this solution. To evaluate this, a model looking at the impact of various levels of pharmacist intervention in patient care—up to and including the ability to prescribe and make adjustments to prescriptions for medication—on systolic blood pressure among patients with poorly controlled hypertension was developed.[3] The study concluded that pharmacist care facilitates better blood pressure outcomes and results in a savings of $6364 per patient over a lifetime. If applied to just half of the roughly 1.86 million Canadians with uncontrolled hypertension, over 500,000

Figure 3. Interface of hypertension cost-effectiveness model (https://cpha.broadstreetheor.com/)[13]

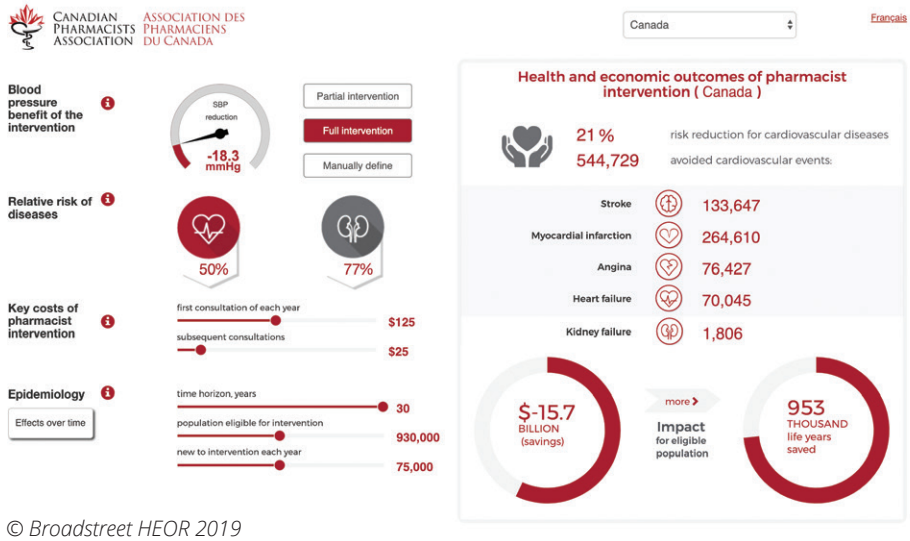
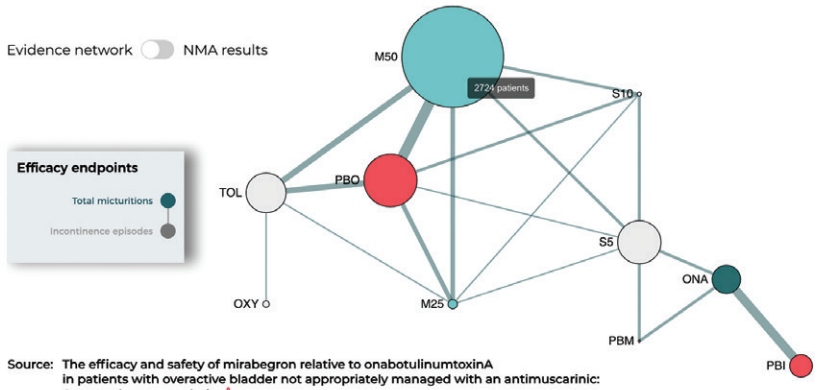
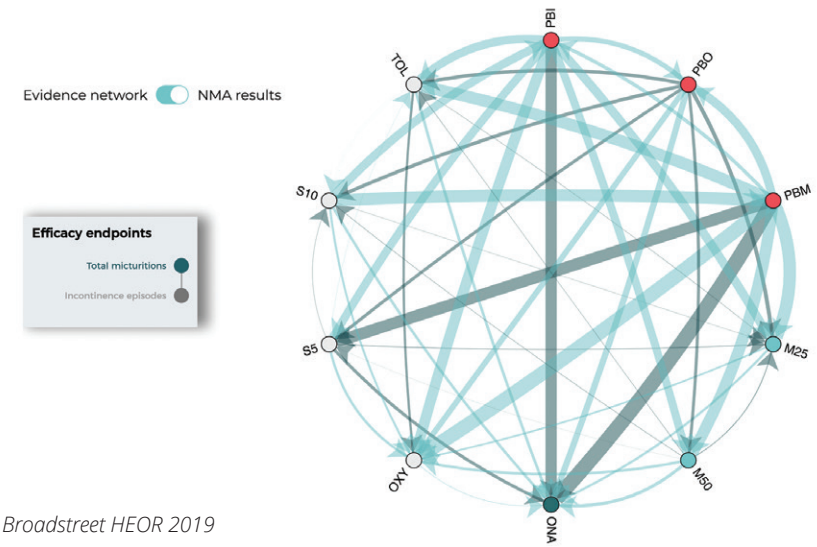


Figure 4. Interactive network meta-analysis visualization. Top shows the network of contributing evidence, with the size of the node corresponding to the number of patients and weight of the line between 2 nodes corresponding to the number of studies contributing evidence. Bottom shows all observed and modeled comparisons, with the weight of the line now conveying effect size.[13]





cardiovascular events would be avoided, for a total cost savings of CDN$15.7B over 30 years.

The robustness of the model results was explored through an interactive "sensitivity analysis" tool (figure 3). The tool allows a skeptical audience to test assumptions of the model, with users able to manipulate and set the level and costs of intervention, the time horizon, and patient populations. The tool is highly customizable, giving the platform the potential to be of international relevance. This is important as HEOR analyses are often used across multiple jurisdictions, targeting a variety of stakeholders, with multiple subgroups and scenarios of interest; customizable interfaces such as this allow for a single analysis to be adapted without the need for voluminous static tables and figures to be generated for all outputs of interest.

The second example is not from the fields of epidemiology or pharmacoeconomics but instead illustrates how HEOR practitioners can learn from what others are doing in data visualization science. The example is an animation published in the *New York Times* in March 2018 comparing the income mobility from birth to late 30s of African American and white men born into wealthy American families.[9] The animated plot garnered quite a bit of attention on social media because of how directly it communicated the fact that black men (who were born wealthy) were far more likely to fall into poverty than their white contemporaries. So how does this relate to HEOR? Traditionally, we might have used a series of cumulative density-function graphs to display changes in a scale score at different time points.[10] Now think about using the same style of animated graphic that the New York Times did to present results of studies describing changes in outcome measures over time at an individual patient level. It could present the trajectory of all patients in a clinical study for selected outcomes, with color coding to represent different trial arms. Such a visualization could powerfully display the beneficial effect of a treatment over time and the limitations caused by missing data and patient dropouts. A good visualization provides a way of understanding effects

in the study as well as just presenting the data. The dynamism of the image with the movement of the dots clearly communicates change over time, while color and position easily transmit further details such as patient characteristics.

A final example focuses on displaying the inputs and outputs of network meta-analysis (NMA) to characterize comparative safety and efficacy. Interpreting the synthesized output of an NMA requires simultaneous consideration of numerous underlying study and population characteristic. Additionally, multiple analytic approaches are undertaken and for large syntheses involving multiple networks, the amount of output can be onerous to review. Data visualization techniques could have an important exploratory and explanatory role here, too; for example, visually explore the impact of heterogeneity, display uncertainty in estimated effect sizes, and compare output across different analytic parameters. A method for visualizing NMA simply and effectively is presented in Figure 4. A dynamic version of the traditionally static network diagram was created where input features can be specified and manipulated, allowing the user to easily assess the full range of outcomes. Features such as study sample size, number of studies, and strength of effect are incorporated visually using established best practices for data visualization, to maximize the amount of information presented simultaneously. The visualization, programmable by using a variety of software options and customizable to the parameters of any NMA, would ideally allow a nontechnical audience to better engage with the underlying data and analytic output.

THE FUTURE OF HEOR DATA PRESENTATION

Data visualization has the potential to make the work of communicating the results of all types of HEOR studies more effective and dynamic. If done correctly, a data visualization can be a powerful tool to quickly encapsulate and communicate study findings and encourage varied audiences to interact with the data. It is also shared more easily on social media. But beyond that, the visual medium speaks to the brain in a way that tabular and text data struggle to—information becomes both more accessible and understandable in greater depth. Effectively and accurately visualizing data can help ensure that researchers, clinicians, and decision makers can understand, digest, and communicate the data, all of which are critical for achieving the ultimate goal of improving patient outcomes.

While interactive visualizations have great potential to aid in knowledge dissemination in HEOR, they must be approached carefully to ensure that they are balanced, unbiased reflections of the underlying data. The development of good practice guidelines may be an important next step in helping to steer HEOR researchers during their adoption of this powerful new technology.

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