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The Big Deal with Big Data: Innovations and Perspectives for the United States

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As healthcare continues to see both vertical and horizontal system integration, systems struggle to handle large aggregates of patient data. Big Data has aided in reducing costs and increasing profits, in understanding patient risk stratification, and helping to determine appropriate interventions. More recently, widespread dissatisfaction with overall healthcare costs and suboptimal quality has led to healthcare leaders searching for new strategies to improve. Big Data not only affords physicians an epidemiological insight necessary to implement widespread change, but also uses retrospective insight, pattern recognition, and predictive power to offer direct and indirect interventions, often coupled with devices or preexisting interventions. Despite some challenges in addressing patient privacy, the paradigm shift from singularly managed patients and data to Big Data systems is underway. Big Data methodologies construe the provider as an agent within a larger community or population organism, one that must adapt and change to suit the needs of those it serves. It allows for the provision of better care, in terms of the care itself provided and the logic of its distribution. In the right hands, if Big Data is the face of healthcare's future, it will be a humanitarian one.

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1 Big Data: From ‘Me’ to ‘We’

As healthcare expenditures in the United States continue to rise to levels well above the national inflation rate, there is a continued interest and obligation to shift towards strategies and innovations that contain costs and further improve quality and outcomes. Though the United States spends almost twice the OECD average on healthcare spending (in USD per capita), national quality and outcome benchmarks continue to place well below those of less developed countries. For a country that often fashions itself as a world-best provider of healthcare, the growing chasm between healthcare expenditures and outcomes has led to the prioritization of reforms and new initiatives aimed at mitigating this discrepancy. As medical record keeping and documentation moves towards electronic platforms, large datasets are available for computational analysis, often revealing patterns, trends, and associations on the individual and group level. In recent years, ‘Big Data’ has been a trending topic for many in the healthcare industry, allowing systems to utilize technological advances and opportunities in the hopes of providing better care, while lowering costs in the process.

The consideration of Big Data in studying population health only began about 200 years ago (Siemens Healthineers, 2015). In tracking the cholera epidemic throughout London, John Snow’s map helped to dispel the miasma theory and locate the source of the outbreak. In in the brief span of time thereafter, there has been much improvement in trending and forecasting, largely due to technology. The application of epidemiological purposes has gradually undergone a paradigm shift from individual tracking to tracking for population health benefits, resulting in technologies and device adaptation to allow for both of these activities during data collection. From a financial perspective, Big Data has allowed systems to identify opportunities to improve profits and reduce overhead (Bresnick, 2017). Electronic Medical Records (EMRs), for example, have allowed physicians and health systems to collect large quantities of data and patient information, which can then be used for risk stratification, to forecast patient trends, and to identify possible interventions.

Considering both perspectives, Big Data has fostered an innovative methodology for systems: data gleaned from the individual are used to attain better understanding of the overall population -- and vice versa. On the one hand, Big Data is often used in the service of heavily-personalized medical care pathways as part of a strategy to help guide patient care throughout a patient’s care encounter; said strategies fall under the umbrella of what is commonly deemed 'population health management'. On the other, aggregated data is used to study disease trends for populations and to tailor community-based interventions and strategies, which may then contribute to improved population health through decreases in patient morbidity and mortality. Furthermore, countries with aging populations can use data to try and find far-reaching solutions to manage patients with high disease burden and chronic care issues (Bresnick, 2017). But with such widespread opportunities for health improvement come manifold challenges in the spheres of implementation and regulation, especially as pertaining to patient privacy.

2 Transition to Big Data: Why Now?

Widespread public dissatisfaction with overall health care costs and soaring premiums has led to wide-spread dissatisfaction with current reimbursement schemas. The shift from fee-for-service (FFS) models to value-based models of care has resulted in new ways to quantify success in disease management at both the individual and system level, contain costs, and enable equal access to and quality of care. This shift, initiated by the Affordable Care Act (ACA), also precipitated a shift in reimbursement methodologies toward an emphasis on patient outcomes, which in turn has resulted in many systems embracing and accepting Big Data as part of their fabric and foundation (McDonald, 2017). Value-based reimbursement schemas, such as that targeting a reduction in 30-day hospital readmissions, have necessitated systems to manage large swaths of patient data, to find trends and opportunities for improvement (Koufi, Malamateniou and Vassilacopoulos, 2015)(OFIs). Better understanding of upstream social and clinical contributors to hospital readmission allows physicians and hospital administrators to increase communication and coordination through the system; with multiple departments working on the same patient and tracking the same information, better care is expected to result from increased diligence towards patient communication, compliance, and oversight (Groves et al., 2013).

Bundled payment programs offer another point of intervention for Big Data. Though recent administrations have further delayed widespread implementation of this cost containment strategy, most systems have implemented bundled payments in cardiology and orthopedics that help track outcomes and costs through the entire episode of patient care. Concurrent with bundled payments, multiple interventions, physicians, and services are tracked and tied to quality and improvement, offering further opportunities to improve care usage data. However, manipulation of datasets requires additional expertise and education, and an efficient data analytics/ information technology (IT) team remains key to ensuring that new payment systems are able to be implemented successfully (McDonald, 2017).

Though Big Data is far from a new phenomenon for companies and strategists, the healthcare industry represents a large opportunity for its integration and application. Patient management and patient-centric approaches have been part of the evolutionary trends that healthcare in the United States has recently experienced, and the efficacy of these approaches stands to increase from the simultaneous adoption of Big Data strategy. The shift toward evidence-based medicine has caused physicians to tailor approaches and interventions based on scientifically-verified results that have shown a special degree of promise among patient populations (Bresnick, 2017). Big Data has allowed evidence-based medicine to be collected at a systemic (and additionally, a national) level. As systems collect vast amounts of patient information, data may be easily manipulated by algorithms to identify trends, successful interventions, and cross-check strategies with additional comorbidities. For physicians practicing in regions of the country that experience high disease-burden with multiple chronic conditions (ex., rural expanses, many CEAC-classified counties, the Deep South), such trending allows them to track large groups of patients and see how different interventions influence results and quality (Wood, 2017).

The overutilization of costly technologies and procedures can drive up hospital and system spending. Global clinical decision support system markets are expected to rapidly rise in the coming years to help address this and other clinical inefficiencies. Such support systems can aid physicians during triaging, diagnosing, and treatment, which would further reduce costs and overutilization of the system. Per reporting by MarketsandMarkets, these global support systems are estimated to surpass $550 million by 2018, at a compound annual growth rate close to 10% between 2013 and 2018 (Siemens Healthineers, 2015). The United States is the foremost user of such systems to date, with over 3500 petabytes of stored data within these. Europe follows with about 2500 petabytes, and then -- a distant third -- Japan with 400 petabytes. As countries continue to shift to EMRs and computerized systems with greater integrative potential, Big Data will be more available to them, leading to expected increases in petabytes stored. Reducing costs is hypothesized as the main driver of this increased uptake, though improved quality and care outcomes, aging populations, and rising disease incidence also play important roles in the uptake.

3 Current Uses of Big Data in Device Sector

The increased utilization of medical apps and smartphone technology has presented a new opportunity for patient tracking and Big Data management. In 2016, mobile health raised $1.3 billion between 622 completed deals, constituting the largest component of total healthcare IT virtual care (VC) funding (Mukherjee, 2017). Increased utilization of smartphones in emerging markets solidifies their place in future markets. Public sentiment is arguably in line with the data: some research has even indicated that over two-thirds of Americans have shown favor for digital health over physical (Elias, 2015). As wireless technology plays an ever-larger role in the day-to-day lifestyle of a working American (i.e., forty-hour workweeks, heavy childcare and supplemental domestic work burdens), prioritizing convenience and ease-of-access will lead more systems to focus on tech-based platforms for patient interactions. Health smartphone apps currently have the highest number of downloads of any category of application (Elias, 2015). Consumerization will further drive physicians to adapt a new, tech-friendly practice, at risk of network leakage to other practices and physicians should they fail to adapt. Regardless, this technological integration of medical information into the hands of patients and consumers will only continue to drive innovation. A concurrent trend is unfolding in wearable devices; serving as a bellwether for this new trend, FDA Commissioner Scott Gottlieb has recently written of a 'Digital Health Innovation Plan' that would allow third-parties to easily and rapidly certify new products that are not as ‘high risk’ as devices (Gottlieb, 2017). It would be expected that Big Data and patient tracking/monitoring apps (Fitbit, etc.) will continue to expand offerings on the market (Ventola, 2014).

As a physician’s tools for diagnosis shift from stethoscope to smartphone, and the doctor’s office waiting room shifts to the patient’s living room, other non-patient facing areas of medicine are also utilizing virtual platforms. One promising current technology, teleradiology, allows for the storage and transmission of radiological images. This Big Data trend comes as a way to ease the access issues radiologists and other physicians experience when trying to compare images, interpret images, and use images as part of evidence-based medicine. Picture Archiving and Communication systems (PACS) is just one example of an IT system used currently (Benjamin, Aradi and Shreiber, 2010). Teleradiology and PACS allow for improved clinical results (final reports that contain useful information) and business results (in scenarios of improved speed of result turnover, patient care, etc.). SuperPACS—a system that allows radiology group serving multiple sites having disparate PACS, research information systems (RIS), and reporting platforms, to view these sites as virtually one site and use one desktop (Benjamin, Aradi and Shreiber, 2010)—help improve global functionality of the radiological sector. Minimizing the burden on local sites and increasing the global nature of the images and information helps to standardize the practice and better identify workflow issues and opportunities for improvement. Additionally, implementation of such systems allows for global access for all referring physicians. Using SuperPACS portals, physicians are able to access information and have a central location and folder for their patients. This sort of communications technology has been reported to be cost efficient, increases remote access to data, and is a logical solution to manage multiple files across multiple locations as the United States continues to see mergers and acquisitions throughout the healthcare and hospital industry (Groves et al., 2013). Unlike other technologies and innovations in radiology, this particular example and application places radiologists as some of the main stakeholders in application, increasing buy-in.

4 Further Reforms and Opportunities in Big Data

Applications and use cases or opens up the potential for interventions and opportunities. The ability to aggregate patient data has been present since the introduction of EMRs, though the brunt of the healthcare industry's capacity to analyze and manipulate these data has only come into play the past couple of decades. As technologies continue to improve and the capability of Big Data extraction expands, healthcare will see furthered developments involving Big Data and healthcare IT. A McKinsey analysis listed four categories that most, if not all, healthcare-related Big Data encompasses (Kayyali, Knott and Van Kuiken, 2013). As healthcare IT continues to expand, and technology increases consumerization, we may expect to see further varieties of Big Data.

4.1 Retrospective Insight

Prior to more recent years, initial applications of Big Data have focused on retrospective insight via retrospective data analysis. Applications and technologies were equipped to take large sums of data and analyze them for researchers. Previously -- and, by most, currently -- patient safety was studied in retrospect: clinical events were identified after being flagged for issues, and then analyzed to identify opportunities for improvement (Weinger et al., 2003)(OFIs). Reducing medical errors and safety concerns is a common goal of systems, and ties into many reimbursement schemas. Big Data, when applied retrospectively, is simply one of the parts to the pathway to reduce medical errors. Data must be extracted from flagged patient files and stratified to identify breakdown and issues in the workflow. Usually in-house committees study these and find common flaws that can be disseminated to medical staff in an effort to reduce future instances of work-flow breakdown. While this approach has been the common norm for most system structures and data reporting, real-time monitoring and flagging of misuse or issues would likely increase safety and quality outcomes in healthcare systems.

4.2 Predictive Power

Pattern recognition artificial intelligence has been proposed as one of the more promising innovations for the future of radiology. Though this does not require radiologist stakeholders, the technology could vastly improve the efficiency and accuracy of imaging. However, research is varied and inconclusive at this stage. The issue of contention is that, though pattern recognition can provide great promise, it requires a pseudo-customization that makes it difficult to implement quickly across systems. In a study (Woo and Kim, 2017), utilization and application of US, CT, MRI technologies was shown to have led to an increase in the frequency of small renal masses being detected. This results in more renal cell carcinoma and benign tumor diagnosis, but no one pattern was found to be sufficient; rather, multiple imaging patterns should have been considered in tandem to then begin to narrow down remarkable images and possibly note malignancy. Should several imaging patterns be integrated and an algorithm created, then there could be a potential for widespread use of pattern recognition, hopefully leading in turn to faster image interpretation with less error. Though initial investments in technology would be quite costly, the return on investment would be more than enough to recoup startup costs, as systems could reduce the amount of budget allocated to overhead costs (specifically: personnel) in the department. Currently, Houston Methodist Hospital employs AI technology that interprets breast x-rays 30 times faster than physicians, and which diagnoses with 99% accuracy (Patel et al., 2017). Though there is a fear that current pattern recognition and the incorporation of AI will eradicate jobs among radiologists, the coexistence of human and machine is an inevitable phenomenon as automation increases and most studies indicate that AI is unlikely to replace radiologists (Krittanawong, 2017). To compensate for any possible disruption, radiologists could continue to subspecialize, and focus on interventions and a more technical application of skills, ones not yet able to be imitated by digital counterparts.

Simultaneously, predictive power can also be applied to help detect and prevent further fraud, waste, and abuse. Systems use patient bills and records to analyze trends and detect anomalies such as overutilization of services, discrepancy of treatment spanning several hospitals within a system and lack of coordination around diagnoses, and prescription filling issues. For example, in implementing Big Data, the Centers for Medicare and Medicaid Services (CMS) prevented more than $210.7 million in healthcare fraud in a year (McDonald, 2017). Similarly, after transitioning to a predictive modeling environment, UnitedHealthCare generated a 2200% ROI after developing methodology to identify inaccurate claims (McDonald, 2017).

4.3 Data Management: Population Health

Big Data's role in population health is not a novel application; however, its potential applications are great and can have a larger impact than present-day. Big Data is able to help providers assess and manage the risk of the populations they serve. Disease trending can allow practitioners to prioritize and strategize initiatives that are most far-reaching for their populations. Community clinics, coalitions, and health fairs are becoming more common as health systems try to increase market share, and provide improved care for their patients and catchment areas.

4.4 Direct Intervention

Diabetes Mellitus (DM) I and II monitors, and continuous feedback loops, have been enabled by the application of real-time Big Data. In constantly relaying information back to a physician or device manufacturer, trends can be analyzed, using target values to indicate when insulin injections are automatically needed (Ventola, 2014). Technologies such as these alleviate the disease burden on the patient, allowing them to potentially live life with less expenditure of effort. In the case of DM patients, continuous feedback devices alleviate the need for the patient to rely on timekeeping values and self-injections. For younger patients (DM I), and those with anxiety and aversion to injections

(DM I or II), continuous feedback devices do the work for the patient and only require routine checkups with the physician and device manufacturer. Large aggregations of patient data also allow physicians to not only study individual disease trends, but also study trends within the patient population in general (Ventola, 2014). This enables them to improve practices and workflow processes. This technology is more cost-efficient than traditional insulin injections and physician visits. Additionally, continuous improvement would drastically decrease ED and physician visits as a result of unmanaged diabetes. Reduction in unnecessary admissions could further help drive down healthcare expenditures.

Wearables, those less invasive than the continuous feedback insulin regulators, also show promise and hope in using patient data in order to help improve patient outcomes in a less invasive approach. Project DETECTED, an “intelligent bra”, is a wearable that is able to detect breast cancer with greater acuity than a mammography, while also reducing a patient to unnecessary exposure (Ferenstein, 2012). Temperature sensors that screen breast tissue are able to track, record, analyze, and identify inconsistencies. These offer an invaluable alternative to mammographies, which have recently been found by multiple studies to be less accurate in detection of abnormalities in women with dense breast tissue. As over 40% of women currently have dense breast tissue, the inaccuracy leads to unnecessary biopsies and a furthering of costly technologies and surgeries. As systems try to consolidate costs, devices such as these offer the possibility for major cost savings and convenience for providers and patients.

5 Implications for Healthcare & Big Data

Going forward, the biggest challenge to the use of Big Data will likely be the integration of Big Data during the paradigm shift from FFS to value-based care. Value-based care, as aforementioned, is organically a more patient-centric approach. As episodes of care are redefined and value-based models are implemented, there will be a necessity to upgrade reporting systems, claims processing, and process automation. Redefining these will lead to patient-centric improvements and outcomes as physicians, nurses, managers, and other healthcare employees will be encouraged to communicate and work together more closely. The alignment of patient and provider incentives, in addition with updated technology that could lead to cost transparency, will help to alleviate the current clinical nuance that plagues the system.

Alleviating the clinical nuance between provider and patient will help to transform current systems from low-value to high-value services. Current models, by contrast, pit the provider and patient against one another and the incentives for patients may not fit into standards and benchmarks set for physicians -- and vice versa.

Patient privacy is one of the top concerns when considering the implications Big Data may have on a system. In light of the summer 2017 cyber-attack on England’s National

Health Service (NHS), additional protections and firewalls should be mandated for Big Data sets, especially those stored in cloud-based platforms (Gordon, Fairhall and Landman, 2017). Unfortunately, studies have cited low organizational vigilance, inadequate staffing and training, and insufficient technology investment as enablers for the susceptibility to healthcare data attacks. With more than 50% of hospitals reporting at least one ransomware attack in the past 12 months, increased budgetary allocations towards intensive training and IT upgrading is an absolute *necessity* of health systems (Gordon, Fairhall and Landman, 2017). Inquiries into the cyberattacks indicated that, while providers had been warned about possible NHS attacks, several computer and processors were outdated and unable to access and download the firewalls necessary to prevent the ransomware attacks. While 'Big Data methodologies' greatly facilitate collection and analysis of data, the pressure to stay abreast of security developments in the IT landscape poses a severe, essential challenge, given that the penalty for failing to do so can be no less than total data exposure (Harsh, Patil and Seshadri, no date).

6 Conclusion

Healthcare's greatest challenge in the era of Big Data will be the necessity of providers to stay updated to change processes, especially with respect to informational security. Continual education and training will need to be added as security updates and technological advances become common-norm of healthcare practices. In particular, Big Data's storage on cloud-based applications requires a market level of protection. The Health Information Technology for Economic and Clinical Health (HITECH) Act was enacted in 2009 to extend HIPAA's requirements to all parties that have access to protected health information (PHI) ('Big Data and Health Disparities -Zhang et al., 2017), but in light of recent provider data breaches, more remains to be done in this area.

As current payment reforms help to alleviate the divide between patient and provider, there will be a new clash—an exaggerated one—between providers and other stakeholders. Owners or manufacturers of imaging technologies may use Big Data to identify underserved patients and disease areas. While possible to be construed as an attempt to provide overall improvement to population health, this initiative could exacerbate overutilization of healthcare, leading to an *increase* in provider costs.

Such phenomena are the growing pains of paradigm shifts. Reconceiving the way providers think about the provision of care necessitates similar shifts in methodologies, workflows, even technologies. And this particular adjustment, this motion from 'Me' to 'We', is one to be embraced, both for its cost-saving potential and for its intrinsic philosophy of holism. Big Data methodologies construe the provider as an agent within a larger community or population organism, one that must adapt and change to suit the needs of those it serves. It allows for the provision of better care, in terms of the care itself provided *and* the logic of its distribution. In the right hands, if Big Data is the face of healthcare's future, it will be a humanitarian one.

References

Benjamin, M., Aradi, Y. and Shreiber, R. (2010), 'From Shared Data to Sharing Workflow: Merging PACS and Teleradiology', *European Journal of Radiology*, vol. 73, no. 1, pp. 3–9.

Bresnick, J. (2017), *Population Health, Big Data Strategies Could Reduce $2B Waste,* Health IT Analytics [Online]. Available at: https://healthitanalytics.com/news/population-health-big-data-strategies-could-reduce-2b-waste (Accessed June 28, 2017).

Elias, J. (2015), *In 2016, Users Will Trust Health Apps More than Their Doctors,* Forbes [Online]. Available at: https://www.forbes.com/sites/jenniferelias/2015/12/31/in-2016-users-will-trust-health-apps-more-than-their-doctors/ (Accessed July 12, 2017).

Ferenstein, G. (2012), *Breast Cancer-Sensing Bra Detects Tumors Years before Some Mammograms* [Online], TechCrunch. Available at: https://techcrunch.com/2012/10/11/breast-cancer-sensing-bra-detects-tumors-years-before-some-mammograms/ (Accessed July 27, 2017).

Gordon, W. J., Fairhall, A. and Landman, A. (2017), 'Threats to Information Security', *The New England Journal of Medicine*, vol. 377, no. 8, pp. 707–709.

Gottlieb, S. (2017), *Fostering Medical Innovation: A Plan for Digital Health Devices,* FDA U.S. Food and Drug Administration [Online]. Available at: https://blogs.fda.gov/fdavoice/index.php/2017/06/fostering-medical-innovation-a-plan-for-digital-health-devices/ (Accessed July 27, 2017).

Groves, P., Kayyali, B., Knott, D. and van Kuiken, S. (2013), *Accelerating Value and Innovation*.

Kayyali, B., Knott, D. and van Kuiken, S. (2013), *The Big-Data Revolution in US Health Care: Accelerating Value and Innovation,* McKinsey&Company [Online]. Available at: http://www.mckinsey.com/industries/healthcare-systems-and-services/our-insights/the-big-data-revolution-in-us-health-care?_sm_au_=iVV7rPs0vW5qNQrM (Accessed June 28, 2017).

Koufi, V., Malamateniou, F. and Vassilacopoulos, G. (2015), 'A Big Data-Driven Model for the Optimization of Healthcare Processes', *Studies in Health Technology and Informatics*, vol. 210, pp. 697–701.

Krittanawong, C. (2017), 'The Rise of Artificial Intelligence and the Uncertain Future for Physicians', *European Journal of Internal Medicine*.

Kupwade Patil, H. and Seshadri, R. (2014), 'Big Data Security and Privacy Issues in Healthcare', *2014 IEEE International Congress on Big Data*. Anchorage, AK, 27.06.2014 - 02.07.2014, IEEE, pp. 762–765.

McDonald, C. (n.d.), *Five Big Data Trends in Healthcare*, ITProPortal [Online]. Available at: http://www.itproportal.com/features/five-big-data-trends-in-healthcare/ (Accessed July 27, 2017).

Mukherjee, S. (2017), *Mobile Health App Venture Funding Hits Record in 2016,* Fortune [Online]. Available at: http://fortune.com/2017/01/17/vc-funding-mobile-health-record/ (Accessed July 27, 2017).

Patel, T. A., Puppala, M., Ogunti, R. O., Ensor, J. E., He, T., Shewale, J. B., Ankerst, D. P., Kaklamani, V. G., Rodriguez, A. A., Wong, S. T. C. and Chang, J. C. (2017), 'Correlating Mammographic and Pathologic Findings in Clinical Decision Support Using Natural Language Processing and Data Mining Methods', *Cancer,* vol. 123, no. 1, pp. 114–121.

Siemens Healthineers (2015), *Big Data in the Healthcare Industry,* Siemens Healthineers [Online]. Available at: https://www.healthcare.siemens.de/magazine/mso-big-data-and-healthcare-1.html (Accessed October 03, 2017).

Ventola, C. L. (2014), 'Mobile Devices and Apps for Health Care Professionals: Uses and Benefits', *Pharmacy and Therapeutics*, vol. 39, no. 5, pp. 356–364.

Weinger, M. B., Slagle, J., Jain, S. and Ordonez, N. (2003), 'Retrospective Data Collection and Analytical Techniques for Patient Safety Studies', *Journal of Biomedical Informatics*, vol. 36, no. 1-2, pp. 106–119.

Woo, S. and Kim, S. H. (2017), 'Differentiation of Small, Solid Renal Masses: A Pattern Recognition Approach', *Seminars in Ultrasound, CT, and MR*, vol. 38, no. 1, pp. 28–36.

Wood, D. F. (2017), *Health Disparities: Big Data to the Rescue?,* U.S. National Library of Medicine [Online]. Available at: https://nlmdirector.nlm.nih.gov/2017/05/16/health-disparities-big-data/ (Accessed June 24, 2017).

Zhang, X. e. a. (2017), 'Big Data and Health Disparities', *Ethnicity & Disease*, vol. 27, no. 2.