

Genomic Medicine in Healthcare – The Tip of the Iceberg

Aditya Pai

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The role of genomic medicine in healthcare is at the tip of the iceberg. Rapid advances in genomics, as demonstrated by the tangible use of gene diagnosis and targeted therapies indicate that the impact of genomics in healthcare is only going to increase. The debate is not “if genomic medicine will impact healthcare” as much as how rapidly it will impact healthcare. However, caution needs to be exercised with respect to three key enablers whose success is critical in order to fully harvest the potential of genomics and successfully integrate genomics in healthcare. These include genomic literacy, privacy and security and IT and the EHR. Health service organizations and healthcare leaders will play a pivotal role in this regard, by beginning to strategize and plan for how they will incorporate genomics into healthcare delivery.

INTRODUCTION

The impact of genomic medicine on healthcare continues to generate healthy debate in the literature (Epstein 2004). The availability of over 1,500 genetic tests and several targeted therapies¹ and the use of pharmacogenomic² data for drug and dosage selection suggest that genomics is already integrated into healthcare and that it will be a game changer. On the other hand, there is scepticism regarding the current and future impact of genomics in healthcare because of the lack of everyday use of such technologies in clinical practice, the questionable clinical utility and validity of some genetic tests and the availability of only a handful of targeted therapies amidst others that have failed clinical trials.

Regardless of which position one chooses to take, recent accomplishments in genomics demonstrate that healthcare stakeholders have a remarkable opportunity – an oppor-

¹ A type of treatment that uses drugs or other substances, such as monoclonal antibodies, to identify and attack specific cancer cells. Targeted therapy may have fewer side effects than other types of cancer treatments (National Cancer Institute N.D.).

² A biotechnological science that combines the techniques of medicine, pharmacology, and genomics and is concerned with developing drug therapies to compensate for genetic differences in patients which cause varied responses to a single therapeutic regimen (<http://www.merriam-webster.com/medical/pharmacogenomic>) Retrieved April 13, 2009.

tunity that promises to increase the uptake of genomics-related technologies such as gene based diagnosis and gene based targeted therapies. Data from a number of recent publications and websites affirm that the current use of genomics in everyday clinical practice represents only the tip of the iceberg. As genomics technologies (e.g., genomic testing) improve in sensitivity and decrease in cost, genomic medicine will reach a tipping point and become an integral part of healthcare delivery, and genetic information an integral part of a person's medical record. Healthcare and wellness decisions will routinely include a genomic component. In the case of chronic diseases in particular, such data will lead to significant pre-emptive measures to prevent the onset of disease years in advance of symptoms appearing.

Key enablers in this regard include genomic literacy, privacy and security and the role of information technology (IT). This paper examines these enablers and outlines opportunities for health service organizations and health professionals to plan for the integration of genomics in healthcare. Genomic medicine will impact healthcare stakeholders in unique ways. Such impacts will not occur in isolation, but will instead converge with advances in IT (e.g., the Internet and electronic health records [EHRs]), communication (e.g., social networking) and other innovative areas of medicine (e.g., clinical research and regenerative medicine).

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WHAT IS GENOMICS?

Genomics includes both “genes” (each of which, alone or in combination, encodes the recipe for assembling all of the proteins found in an organism) and “non-coding sequences” (those portions of the DNA sequence for which no function has been identified). The genetic alphabet contains four nucleotides bases – adenine, guanine, cytosine and thymine – which chemically combine in pairs: adenine with cytosine and guanine with thymine. It is estimated that there are three billion base pairs in the human genome and approximately 20,000–25,000 protein-coding genes. Clearly, the billion-plus data elements needed to define even one person's genetic signature are several orders of magnitude more complex than the few hundred to few thousand data points in a traditional medical record.

WHAT IMPACT WILL GENOMICS HAVE ON HEALTHCARE DELIVERY?

The impact of genomics on healthcare delivery will be significant. Rather than dealing with diseases after they have manifested themselves, genomics allows clinicians to look into a person's future and determine what diseases that person is susceptible to and which drugs and interventions hold the highest likelihood for success. It changes healthcare from retrospective, interventional care to prospective, preventative care that is highly personalized and pre-emptive. The true value of genomic medicine rests in understanding and incorporating genomic information, both from clinical and research outcomes, into a person's health record. In the next decade, the impact of genomics on healthcare will be significant. Genomics will become an integral part of a person's medical record for the following reasons:

- The cost of sequencing an individual complete genome will decrease from hundreds of thousands of dollars to under \$1,000.
- The use of whole-genome association studies will increase.

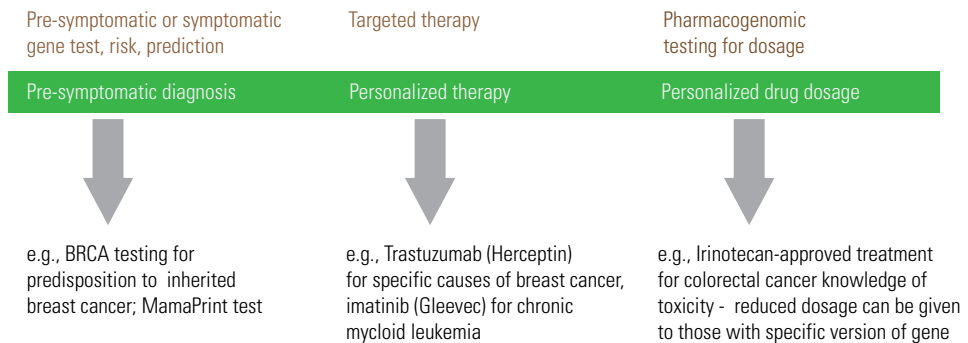
- Robust genomic algorithms for common yet complex conditions will be developed.
- New targeted therapies will pass clinical trials.

Genomic medicine will also have a significant impact on healthcare delivery due to its intensely personal, predictive, ethical, legal and social dimensions and impacts. For example, a woman with a strong family history of breast cancer may choose to have genetic testing for mutations in *BRCA1* and *BRCA2* (predisposition genes in which variations or mutations have been associated with breast and ovarian cancer). A negative result for *BRCA1* and *BRCA2* mutations would mean that her risk for breast cancer is reduced, but not erased. Conversely, a positive result for *BRCA1* or *BRCA2* mutations would mean that she faces an increased risk for breast and ovarian cancer. She would then face emotional upheaval on learning her risk for breast and ovarian cancer and a very personal choice regarding what to do with this information (e.g., prophylactic mastectomy and oophorectomy, sharing this information with other family members). Genomic testing therefore creates a new demand for people who can interpret and accurately and compassionately deliver such information.

IS GENOMICS ALREADY IMPACTING HEALTHCARE?

Genomics is already impacting healthcare, although mainly in specialized settings. Figure 1 depicts early successes in specific types of cancer, where genomics has already enabled pre-symptomatic diagnosis, personalized therapy and personalized drug dosages.

Figure 1. Genomics enabled approach to specific cancers



Among various new medical technologies and treatments in genomic medicine, molecular diagnostics and targeted therapies are already commonly in use.

Molecular Diagnostics

Molecular diagnostics involves diagnosis or risk analysis using an individual's unique genetic data. These data provide a basis for diagnosis and, if possible, a determination of personalized treatment(s). Molecular diagnostics broadly includes prenatal testing, predisposition testing, pharmacogenomic testing and molecular imaging (MI).

Prenatal testing includes testing for chromosome disorders such as Down syndrome and newborn screening (e.g., newborns are screened for 28 disorders, including cystic fibrosis, in Ontario).

Predisposition testing includes testing for *BRCA1* or *BRCA2* mutations for breast cancer. *BRCA1* and *BRCA2* are not “breast cancer genes” per se. However, the presence of mutations in these genes increases the lifetime “likelihood” of developing breast cancer and other cancers, such as ovarian cancer. Predisposition testing can also test for rarer gene disorders that manifest in adulthood (e.g., Huntington’s disease) and common conditions that are termed “multi-factorial,” with varying genetic and environmental components (e.g., diabetes, heart disease).

Pharmacogenomic testing enables an understanding of how an individual’s genetic variation for specific drug-metabolizing enzymes may affect the body’s response to the drug being administered (Epstein 2004; Johnson 2003). For example, specific pharmacogenomic profiles of cytochrome P450 genetic polymorphisms influencing metabolism (*CYP2C9*) and pharmacodynamic response (*VKORC1*) are strongly associated with responsiveness to warfarin, a commonly used anticoagulant. Using such profiles to adjust warfarin dosage can prevent complications of warfarin treatment. The US Food and Drug Administration has approved the inclusion of pharmacogenomic information in the warfarin package insert.

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MI is a new discipline that meshes molecular biology and *in vivo* imaging. In MI, probes known as biomarkers are used to image specific targets or pathways such that cellular function and molecular processes can be visualized in living organisms. MI is currently being used for the earlier and more accurate diagnosis of neurological and cardiovascular diseases and cancers as well as for improved treatments.

Targeted Therapies

Instead of the more traditional blockbuster “one size fits all” pharmaceutical model, targeted therapies offer a fundamentally different approach for therapeutic use. Most drugs produce a spectrum of responses in various people: from no effect in some, to a moderate effect in most, to an absolute cure in a few. Targeted therapy aims to identify those persons for whom a given drug is highly efficacious, and avoid giving the drug to those in whom it will have little or no effect. This not only provides a path to novel therapies, but also rehabilitates older drugs that have cured some people, but on average have had little effect or been overly toxic.

The genomic approach toward drug-target isolation offers significant advantages over the tried and tested approaches that pharmaceutical companies have used. Once molecular data (e.g., generated by the International HapMap Project, <http://www.hapmap.org/thehapmap.html.en>) from a sample population affected with a specific common disease provides an association between a gene and a protein product, developing a targeted molecule can be much more successful. Such therapies are precise and hence possess high efficacy, but often only in a subset of individuals with a specific condition. Tables 1 and 2 give examples of novel genetic tests and targeted therapies.

The cost–benefit ratio of such treatments is debatable. For example, screening for and treating phenylketonuria provides net direct cost savings to society. However, the treatment in such a case is dietary. In the case of imatinib, a first-line therapy for chronic myeloid leukemia, a six-year increased survival rate over interferon-alpha therapy has been noted, with a \$43,100 per life-year saving (Reed et al. 2004).

Prenatal genetic testing, genetic predisposition testing and pharmacogenomic testing are three categories of tests which are regularly being offered to healthcare consumers today. However, data from research studies detailing clinical outcomes based on pharmacogenomic testing and the appropriate dosage of specific drugs remain sparse. Similarly, data on clinical outcomes associated with genetic and genomic interventions are more the exception than the norm (Scheuner et al. 2008).

Table 1. The business of genetics – examples of molecular diagnostic testing

Three companies offering molecular diagnostic testing
Genomic Health Inc offers a molecular based test – OncotypeDx, which analyzes the expression patterns of a panel of 21 genes and provides a likelihood of breast cancer recurrence in women with newly diagnosed early stage breast cancer. In addition, this test is also able to predict the benefits from certain types of chemotherapy. Thus, based on the results of this test, it is possible to screen for and differentiate women with a specific type of breast tumour who may not benefit from chemotherapy.
Genzyme offers a comprehensive menu of genetic testing for single gene disorders e.g., An example is its Ashkenazi Jewish panel, which determines carrier status for a number of genetic conditions that occur more frequently in the Ashkenazi Jewish community.
Navigenics offers a Health Compass package which includes 24/7 access to genetic counsellors ongoing, secure, personalized updates for an entire year, adding new condition predispositions, new markers, new clinical therapies, other wellness strategies, and easy-to-use, relevant health information.

Table 2. The business of genetics - three targeted therapies

Three targeted therapies
Trastuzumab therapy is used in women who have metastatic breast cancer and a specific HER2/NEU genetic alteration.
Gefitinib is an anti-cancer drug for patients with recurrent non-small-cell lung cancer who have specific mutations within a specific gene. Through genetic testing, candidates for gefitinib (instead of chemotherapy) can be identified.
Imatinib is a drug therapy that affects the molecular cause of chronic myeloid leukemia. Imatinib acts by specifically interfering with an abnormal protein, thereby preventing it from overproducing white blood cells.

HOW WILL GENOMICS IMPACT HEALTHCARE IN THE FUTURE?

Genomic medicine is expected to have the following profound impacts on the future of healthcare:

- Transformation of healthcare delivery – genomic medicine is expected to allow the delivery of personalized care by professionals who understand the medical, ethical, legal and social implications of genomics information when applied to healthcare consumers. Healthcare delivery in such cases includes the spectrum from molecular

diagnosis to targeted treatments, as compared to a “one size fits all” approach.

- Transformation of person management – genomic information may be incorporated into key health-related decisions involving surgery, treatment and drug regimens. The likely scenario within a decade is the common availability of whole-genome sequencing with a pharmacogenomic profile that provides a comprehensive risk assessment for various genetic and multi-factorial conditions and a list of personalized drugs with personalized dosages based on an individual’s genotype. The costs for gene sequencing and whole-genome association studies using gene chips with 550,000 single-nucleotide polymorphisms (SNPs),³ for example, have steadily fallen, with costs presently halving approximately every 22 months (Guttmacher and Collins 2005). This closely resembles Moore’s law, which applies to increased computing power and decreased costs. By 2014, it is expected that an individual’s personal genome sequence will become a permanent aspect of his or her EHR, at a cost of \$1,000 (US) (Guttmacher and Collins 2003).
- Proactive prevention versus reactive treatment of chronic diseases through earlier and more robust risk assessments, which will include genomic data.
- New business models for the pharmaceutical industry, which will be facing patent expirations, threats from biotechnology companies, regulatory pressures, costly drug development timelines and backlash from adverse drug reactions. Genomics holds the promise of realizing value from enormous past investments in drug candidates that were eliminated due to person-specific toxicities or lack of efficacy.
- Redefining clinical trials based on population stratification and the use of pharmacogenomics and MI.
- Novel applications of genomics extending to areas such as infectious diseases and other public health issues.
- Convergence with multiple new pervasive and emerging technologies such as Web 2.0 (Genome 2.0), novel medical devices and regenerative medicine.

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WHAT ARE THE KEY ENABLERS FOR GENOMICS TO INTEGRATE IN THE DELIVERY OF HEALTHCARE?

To successfully harness the full potential of genomics and successfully integrate genomics in healthcare, the following three enablers are critical: genomic literacy, privacy and security and IT and the EHR.

Genomic Literacy

Genomic information is personal. The use of such information is predicated upon individuals understanding both the short- and long-term impacts of such information. Genomic literacy is a crucial aspect in the dissemination and integration of such information in healthcare. However, genomic information can be complex and hard for an end consumer to interpret. For example, the fundamental difference between a screening test and a diagnostic test at the consumer level is a concept that can be difficult to understand. Thus, even the most well-informed, “Google-centric” consumers can have difficulty in understanding and interpreting genetic results and the impact of such information on their lives.

³ A variant DNA sequence in which the purine or pyrimidine base (e.g. cytosine) of a single nucleotide has been replaced by another such base (e.g., thymine) (Merriam-Webster Online N.D.).

The medical community is not exempt either, as studies have shown a low level of understanding of genomics information among general practitioners and specialists (Baars et al. 2005). Scheuner et al. (2008) analyzed 68 peer-reviewed research articles and reviews from the past decade in an effort to better understand the current state of genomic medicine for common conditions such as heart disease, diabetes and cancer. Apart from finding a lack of sufficient outcomes-based data, they found that healthcare workers, while enthusiastic about genetic testing, often did not have the time, skill or knowledge to refer at-risk persons to specialists for genetic tests and/or consultation. In general, healthcare workers were felt to be under-prepared to deal with genetic and genomic data in their practices, pointing to the attention that needs to be paid to genomic literacy.

Currently, genomic information is largely provided by trained geneticists (physicians with specialized genetics training) and genetic counsellors (master's-degree-trained certified professionals). Given the future impact of genomics technologies on healthcare, physicians and other professionals are unlikely to have the necessary genomics knowledge to truly do justice to the available technology.

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Jane is pregnant and arrives at a genetic clinic for prenatal genetic counselling. While taking her family history, Hana, the genetic counsellor, is told by Jane that her husband has a family history of Huntington's disease (HD), a debilitating neurological condition that presents in people in their 40s and eventually leads to dementia and death. Jane informs Hana that her husband does not wish to determine if he has the altered gene for HD. Hana spends the next 30 minutes explaining the inheritance of HD, the testing that is available, along with its benefits and limitations, and the risks to Jane's unborn child. Upon hearing the information, Jane states that she wants to have prenatal testing for HD. This complicates matters because if the baby has the altered gene, it means that Jane's husband, despite his explicit choice of not wanting to know his HD gene status, will now know his status. This leads to multiple counselling sessions with both Jane and her husband before the couple make their decision. This scenario requires professionals to have both scientific and psycho-social expertise in communicating and helping people to arrive at an informed decision.

The sidebar gives a present-day scenario depicting some of the complexities involving educational and training resources that genomics information entails.

With a growing supply and demand for genomics services, the importance of qualified professionals who can do justice to understanding and communicating sensitive information to individuals seeking such testing will be key. The role of the family physician will change, as these professionals will have to take an increasing responsibility for providing genomics information. Innovative educational methods, a telemedicine-type service with a genetics component (telegenetics) and portals that allow people to explore their genetic data will likely be demanded by consumers. For example, Informed Medical Decisions (Informed, <http://www.informeddna.com/about.html>) is already providing remote, telephone-based genetic counselling to people at their convenience, and was created to increase access to experts in cancer genetics for people

at risk for hereditary cancers. Through Informed, Aetna, a large insurance company, is now offering its members confidential telephone and web-based cancer genetic counselling services as part of their health benefits. Similarly, consumer genomics companies are offering portal-based services to consumers interested in tracking their genomics information.

Privacy and Security

Privacy and security are critical if genomic medicine is to successfully integrate into healthcare and has been discussed at length in the context of healthcare and EHRs. In recent years, personal health information has been subject to legislation such as the *Personal Health Information Protection Act* and the *Personal Information Protection and Electronic Documents Act* in Canada and the *Health Insurance Portability and Accountability Act* (HIPAA) and, most recently, the *Genetic Information Nondiscrimination Act* (GINA) in the USA. Given the likelihood of a \$1,000 personal genome test, and the advent of genomics companies offering direct-to-consumer genetic tests, the importance of the privacy and security of genomic information cannot be understated.

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Key privacy and security factors influencing the integration of genomics into healthcare include consumer confidence regarding the privacy and security of their genetic information as it relates to their medical record. Data have shown that consumers are keen to learn how genetic information can be of benefit. On the flip side, consumers are also concerned about the misuse of genetic information by employers and insurance companies. Corporations such as IBM have taken a leading role in explicitly outlining a policy regarding non-discrimination based on genetic information (IBM 2007). In this regard, GINA protects consumers from discrimination by health insurers and employers on the basis of genetic information and also strengthens HIPAA safeguards by limiting insurers' ability to use genetic information to raise rates for an entire group and by extending protection to individual health insurance plans (Hudson et al. 2008).

Information Technology and the Electronic Health Record

IT and the EHR are two of the most significant enablers for genomics to realize its full potential in healthcare. The greatest power of genomic information lies in its personalized molecular information and predictive power – either the evidence of a direct alteration in a specific gene or in the expression of a gene or set of genes, or an association of a set of genes or markers (such as SNPs) with a disease allele. These data become powerful when used in tandem with phenotypic data such as physical traits, standard blood work, imaging data, allergies and other medical data. Yet today, EHRs, electronic medical records (EMRs) and personal health records (PHRs) are all evolving along different trajectories. In most jurisdictions, albeit with some exceptions, it is still unclear which medical record will hold which clinical or personal record. Given the considerable overlap, ultimately, a truly integrated medical record – one that has the ability to reconcile a person's medical record with his or her genetic and phenotypic history and enable predictive analysis – will be required.

Health regions and academic medical research centres (AMRCs) will need to have the necessary IT infrastructure to store, mine and systematically integrate genomic infor-

mation with various sources of clinical and research information and outcomes-based data. Genomic data will increasingly involve the simultaneous testing of thousands of genes and their expression patterns.

Non-research healthcare providers, which include community hospitals, large non-teaching hospitals and family health practices, will primarily be consumers of genomics (e.g., family health practices will use genetic test results provided by reference laboratories). It will, however, still be important for non-research healthcare providers to have the IT infrastructure to be able to view and integrate genomic and phenotypic data from disparate sources.

For example, it is expected that data produced from diagnostic gene-based tests will be like other laboratory tests, linked to an interoperable EHR (e.g., laboratory information data would include genetic tests and link them back to a person). Local EMRs in facilities will need to be stored, linked and provide health data (including genetic data) and some form of clinical decision-making tool to physicians and genetic counsellors that incorporates genetic algorithms for the genetic conditions at hand. Interoperable EHRs will provide constant access to an individual's health record. For any healthcare provider, EHRs are the catalyst that would allow for the systematic integration of genomic data within an individual's medical record. From the consumer perspective, an integrated medical record, including the impact of genomic information, would be provided by provider portals and PHRs – akin to the commercially available portal-based views offered by consumer genomics companies today. This will also require current discussions on EHRs to include a “genomics view” as part of a longitudinal EHR.

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OPPORTUNITIES FOR HEALTH SERVICE ORGANIZATIONS AND HEALTH PROFESSIONALS

Health service organizations and health professionals have a tremendous opportunity to harness the power of genomics by incorporating genomics information in several ways.

Chronic Disease Prevention and Management

As gene testing and genome-based targeted therapies become more pervasive and whole-genome scans become available, it will be possible to obtain a more accurate risk assessment for predilection to chronic diseases. Health regions and hospitals can tailor their chronic disease prevention and management and health and wellness programs based on such information, and begin to focus on molecular-based, proactive prevention. While it is well documented that the genetic component of various common disorders can vary, the use of such information can nevertheless be significant in offering personalized medicine to consumers. In this regard, genomics data should be actively included in chronic disease management strategies.

Genomic Literacy

The lack of genomic literacy may be a significant stumbling block in its integration. As genomic medicine increases in use, health regions and hospitals need to engage in genomics education by providing tools and multiple channels for consumer education, including the use of portals, telemedicine and both traditional and non-traditional means. Investing in genomic literacy will result in more informed consumers who can

begin to take personal responsibility for their health and wellness decisions. Similarly, educating healthcare professionals (e.g. training and using genetic counsellors in multi-faceted ways) cannot be underestimated, given the lack of adequate numbers of professionals who possess the skills to offer counselling to consumers.

Innovation

Genomics represents cutting-edge, innovative science. Health service organizations and professionals can become truly innovative by actively adopting a genomics strategy and action plan. For a health service organization, for example, articulating how it will prepare for and use genomics information for the health and wellness of its consumers can raise the innovation bar and competitiveness of the organization. This can result in attracting leading researchers and professionals to the organization. Innovation (defined by the late Peter Drucker as “change that creates a new dimension of performance”) (Hesselbein et al 2002) will require various key healthcare stakeholders belonging to both the private and public sectors, and spanning the healthcare industry, to work together by investing in the appropriate IT and attracting the right skills.

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Policy Leadership

Policy setting is vital for genomic medicine to be applied at the population level. For example, policies regarding the privacy and security of genomic information, the reliability of genomic data and the applicability of genomic data to specific populations are vital components that need to be addressed by healthcare regions. Healthcare regions and provinces have a big opportunity to play a leadership role in developing policies that are in the interests of their consumers, while encouraging innovation.

Making the Leap to Genomic Medicine

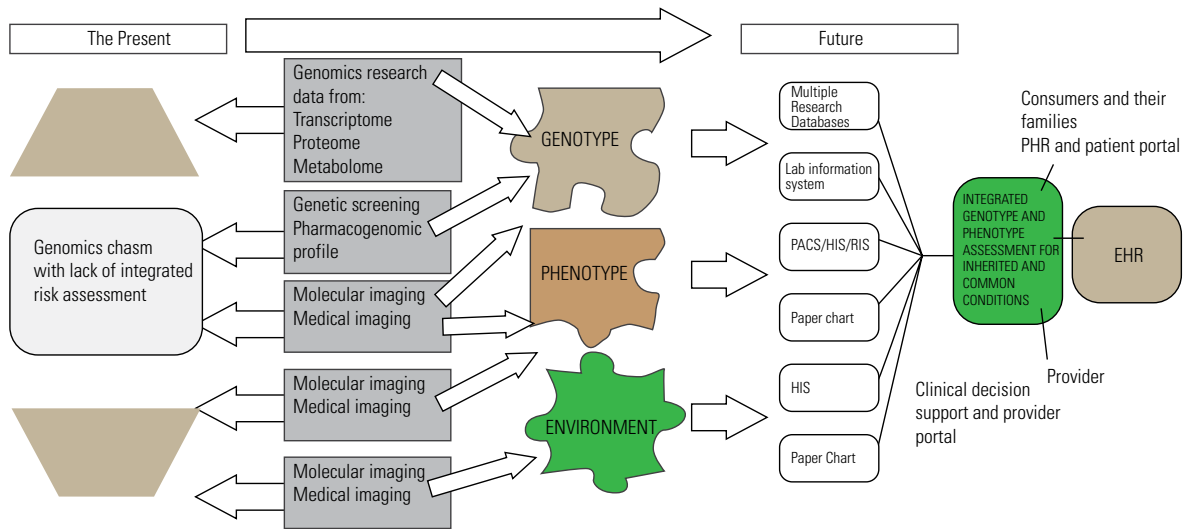
For an organization or healthcare region to make the leap to genomic medicine, healthcare leaders will need to invest in a sound genomics strategy, create strong alliances with the private sector and other healthcare stakeholders and develop a vision for personalized and proactive preventative care of consumers. As an example, Figure 2 depicts a transformation from the present state (lack of integrated risk) to the future state for large AMRCs where research and clinical information are integrated. In this example, the following actions are illustrated:

- Disparate sources of clinical, laboratory and research data are integrated.
- A genetic intake is stored in the AMRC’s EMR.
- A consent management system within the AMRC allows for consent to designated providers.
- A provider portal allows for easy access to genetic information.
- Since most genetic consults are multidisciplinary, information in electronic format is quickly available to a provider such as a physician/genetic counsellor.
- Research findings, such as new genotype–phenotype correlations, can be integrated into diagnostic tests and alerts can be sent to providers when this occurs.
- Consumers have access to a portal and PHR where they can plan their follow-up as well as learn more about the condition they are being tested for.
- This information can be shared electronically with the EHR.
- Greater efficiencies result, owing to less duplication of services. In addition, providers

can view and practice evidence-based personalized medicine (e.g. a pharmacogenomic profile may suggest a specific dosage, which is calculated through a clinical decision intelligence tool).

- The large AMRC is a leader in genomic literacy and plays a key role in genomics policy setting.

Figure 2. The Leap to Genomic Medicine



CONCLUSION

The current role of genomics in healthcare represents the tip of the iceberg and is only going to increase in the years to come. Genomics tests, for example, are still focused on traditional genetic conditions versus more common chronic conditions that are seen in the population. However, personalized genomic scans (although they have their critics) are nevertheless available to today’s consumers. The continued role of pharmacogenomic screening is evident through its association with key drug-metabolizing pathways. As better outcomes-based research becomes available on these associations, tailoring of medications based on pharmacogenomic profiles will become a reality. A handful of targeted therapies, such as imatinib and gefitinib, are currently being used. Numerous others are in various stages of clinical trials (e.g., therapies for Alzheimer’s disease, multiple sclerosis) and, upon drug approval, will be offered to consumers. Similarly, the use of MI for diagnosis and research is in its early stages.

The above evidence demonstrates that the current role of genomics in healthcare represents the tip of the iceberg – genomics is already here, more is coming (the rest of the iceberg) and it will be a “game changer.” Instead of debating whether genomics is really impacting healthcare, it will be prudent for healthcare leaders to grapple with how quickly the game will change as a result of genomics. However caution needs to be exercised, given the importance of the success of enablers such as genomic literacy, privacy and security of genomic information and the key role that IT will play in this regard. For example, the varying evolutionary trajectories of EMRs, EHRs, PHRs and an

integrated medical record, coupled with technical and policy safeguards for privacy and security, will all impact the rate of change as a result of genomics. Genomics technology will also not occur in isolation, but instead will converge with other innovative technologies such as regenerative medicine, Web 2.0 and other emerging medical technologies. Health service organizations and leaders will play a pivotal role in this regard, and can begin by strategizing and planning now for how they will incorporate genomics into healthcare delivery. Table 3 shows 10 takeaway points for a healthcare leader.

Table 3. Ten takeaways for a healthcare leader

<ol style="list-style-type: none"> 1. Include genomics in your innovation agenda. 2. Take a leadership initiative in genomic literacy by investing in genomic education for key staff. 3. Invest in IT at an enterprise level and strive to eliminate silos between the clinical and research aspects of your organization. 4. Debunk the “will genomics really happen?” myth – it is already happening and will continue to impact healthcare. 5. Participate in and lead policy discussions about genomics. 6. Attract the best people in genomics to raise the innovation bar for your organization and/or healthcare region. 7. Prepare for the intensely ethical, legal and socio-economic impact of genomics on healthcare. 8. Include genomics in chronic disease management and health and wellness strategies and discussions. 9. Adopt sound privacy and security policies and controls (and build staff and consumer awareness of the privacy risks/threat) that can withstand the personalized nature of genomics data. 10. Expect consumers to demand new genomic technologies.
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About the Author

Aditya Pai, MSc, MSc, MS, MBA, CGC, is managing consultant, IBM Global Business Services, Healthcare Practice.

