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Do physicians think genomic medicine will be useful for patient care?

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Abstract

Significant technological improvements over the last decade have led to a vast expansion in the understanding of the genomic architecture of human disease. However, the use of genomic information, so-called genomic medicine, in routine clinical care, has been slow in comparison to the growth in genomic discovery. The uptake of genomic technology into clinical practice will depend on physicians' perspectives of its utility in patient care. We review recent literature addressing physician attitudes regarding the usefulness and limitations of genomic testing. We conclude by proposing research areas to better understand the role physicians will play in the uptake of genomic information into clinical medicine.

Keywords

clinical utility; genomic medicine; genomic testing; pharmacogenomics; physician perspectives

Over the last decade since the complete sequencing of the human genome, technological innovations have made it possible to identify human genetic variation more accurately and efficiently, accelerating our ability to perform large-scale genomic studies to identify new associations between DNA variants and human disease. This technological progress has resulted in the ability of an individual to examine his or her entire genome for disease-

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associated variation, as opposed to focusing only on a specific gene or genes. In this paper, we use ‘genomic testing’ to mean any genotyping performed across an individual’s entire set of genes. One such technology is the SNP array, which examines an individual’s genotype at hundreds of thousands or millions of loci known to carry genetic variation common in the population. This technology has enabled genome-wide association studies (GWAS) that have uncovered associations between such SNPs and a diverse spectrum of diseases [1,2]. SNP arrays are also the basis for commercial direct-to-consumer (DTC) genetic testing by companies like 23 and Me, Inc., which has for several years marketed a test for ancestry-informative genetic markers and, until recently, for common disease-associated variants [3,4]. A second type of genomic testing is array comparative genomic hybridization, which detects copy-number variation, deletions and duplications of segments of DNA. Such testing has been most widely applied to perinatal diagnosis of rare syndromes and molecular characterization of cancer [5,6]. The most complete examination of an individual’s genome is now possible through a third type of genomic testing, next-generation sequencing, which can genotype the majority of the human genome’s 3 billion DNA base pairs (whole-genome sequencing) or just its protein-coding regions (whole-exome sequencing). This approach identifies common variation but also, unlike SNP arrays, allows the discovery of novel, often rare, genetic variation. As much of the variation uncovered by sequencing is very rare, the associations between sequenced variants and disease are less well studied, making clinical inferences challenging at present. However, sequencing technologies have recently been employed to elucidate the genetic etiologies of rare syndromes, demonstrating proof of concept of their application to clinical medicine [7,8]. What the genomic testing technologies above have in common is the ability to expand genotyping beyond single genes to the entire human genome simultaneously in a single test.

Traditional genetic testing has had two broad, sometimes overlapping, clinical applications: diagnosis and risk prediction. In the former, identification of a lesion in a gene or gene product known to be associated with a given disease can confirm a suspected diagnosis. One example is the diagnosis of cystic fibrosis from the detection of one of the well-characterized mutations in the *CFTR* gene. An example of genetic testing for risk prediction is testing for stereotypical mutations in the blood clotting factors prothrombin and Factor V, which can aid in assessing one’s risk for venous thromboembolism. Genomic testing might be similarly applied for diagnosis and risk prediction. Next-generation sequencing has aided in the diagnosis of syndromic diseases, identifying rare genetic variants not detected by conventional diagnostic testing [7,8]. SNP arrays can use genotype at multiple loci across the genome to inform one’s genetic susceptibility to a common disease such as Type 2 diabetes [9,10].

The reduction in the cost of genomic testing and the numerous new associations between genomic loci and human disease have brought anticipation that genomic testing will soon penetrate routine clinical care, both for common and rare conditions. Physicians now stand at the interface between genomic discovery and patient care. Their perception of the utility of genomic testing, then, will be an important determinant of whether it sees widespread uptake into clinical medicine. Here, we discuss a selection of recent studies that shed light on the question of whether physicians think genomic medicine is useful for patient care. In

particular, we focus on studies that have assessed how generalists, including primary care physicians, view this new technology. While many of the questions addressed in this perspective have analogs in pediatrics, we limit our discussion to the care of adult patients, because the ethics of applying genomic medicine to the clinical care of children is beyond the scope of this paper. We conclude by suggesting research areas needed to further identify how physicians might shape the future clinical integration of genomic testing.

Physicians' general attitudes to genomic testing

Several physician surveys have been recently conducted to address the question of physicians' perceived utility of genomic testing. In 2008, Scheuner *et al.* published a systematic review examining the delivery of genomic testing for common chronic diseases [11]. This systematic review identified numerous studies citing generally positive attitudes among physicians regarding the perceived clinical benefits of genomic testing. However, the study highlighted limitations in physician understanding of genomic medicine, including knowledge gaps among physicians regarding genetic and genomic testing for common chronic diseases. It raised concerns about privacy and discrimination as a common barrier identified across multiple physician surveys. The study also described challenges in integrating genomic testing into primary care practice, including the discrepancy between the medical workforce available and that needed for the growth of genomic medicine.

Since this systematic review, there have been several important studies of physicians' use of and attitudes regarding genomic testing. Two physician surveys, one of primary care physicians [12] and the other of generalists and specialists at two academic medical centers [13], cataloged the current clinical use of genetic tests and found intermittent testing for monogenic disorders such as Factor V Leiden for venous thromboembolism risk or *BRCA1/2* for breast cancer but rare use of genomic testing of any kind. Using the model of Type 2 diabetes, Grant *et al*. conducted a national survey of general internists and endocrinologists to assess physicians' perceptions of the clinical utility of genomic testing for common chronic disease [14]. In that study, most physicians reported 'Somewhat' or 'Very' positive opinions of genetic testing and would recommend a genomic test to a patient, and 47% of physicians were 'Very likely' to recommend a genomic test directed at optimizing diabetes medication. Similarly, in a nationally representative survey of approximately 500 US primary care physicians regarding DTC testing, Bernhardt *et al.* found that 40% of respondents agreed or strongly agreed with the statement: "At this time, genetic testing for risk for common diseases offers information that is clinically useful." More telling was that 40% of respondents neither agreed nor disagreed with the statement, suggesting uncertainty in their opinions [12].

In 2011, Powell *et al.* conducted a survey of physicians' knowledge and attitudes regarding DTC testing among 382 primary care providers in North Carolina and found that a minority of survey respondents (38%) were aware of DTC genetic testing, and only 15% were prepared to discuss DTC testing with patients [15]. Among those who reported awareness of DTC testing, approximately 40% believed that it was clinically useful, comparable to the findings of Bernhardt *et al.* described above. The views of physicians and genetic counselors towards DTC testing were recently reviewed by Goldsmith *et al.*; studies in the USA, Japan

and Greece showed variable physician awareness of DTC but generally positive views of its usefulness among those who were aware [16]. Although focusing more on genetic instead of genomic testing, Mainous *et al.* found similar results. In their survey of 1311 family physicians in Canada and the USA, approximately 70% of physicians believed genetic testing was at least 'Somewhat valuable' in primary care, regardless of whether they self-reported as 'Somewhat or very knowledgeable' or 'Not knowledgeable' about genetic testing [17]. Using semistructured interviews to assess behavioral beliefs regarding genomic testing among primary care and specialist providers at a Veterans Health Administration clinic in Texas, USA, Arar *et al.* found that all 20 providers studied felt that genomic testing would be valuable in clinical medicine [18]. This positivity is reflected in other recent surveys that have reproducibly found that 40–60% of physicians, again spanning primary care providers and specialists, believe genomic testing will have value in clinical practice [13,19].

Another interesting finding is a physician perception that genomic testing will be of greater utility in the near future. In the Bernhardt and Mainous studies, 50% and 70–80% of primary care and family practitioners, respectively, believed that genomic testing will be clinically useful in 5 to 10 years [12,17]. This anticipated increase in the clinical utility of genomic medicine could reflect an acknowledgement of the progress in genomic discovery. That the perceived utility of genomic medicine is not higher at present may reflect the realistic understanding that its clinical integration will depend on its ability to contribute to improved patient care and on the ability of health systems to adopt it.

The Grant *et al.* study described above formulated a general framework for the clinical utility that genomic testing might have in three domains: risk prediction and its consequences for clinical management, motivating behavior change, and guiding pharmacotherapy [14]. This framework is useful for evaluating more recent studies of the perceptions physicians have of the clinical utility of genomic testing. Below we describe the literature on physicians' attitudes and perceptions of genomic testing in each of these three domains.

Risk stratification

In the Grant *et al.* study, greater than 70% of surveyed physicians reported either somewhat or very positive impressions of genetic testing to assess common disease risk, while only 22% of the same physicians would be very likely to recommend a patient for a genetic test to assess diabetes risk. While that survey focused on Type 2 diabetes as a paradigm for the application of genomic testing to common chronic disease care, the findings highlighted a discrepancy between generally positive attitudes about genomic testing and uncertainty about its specific application to risk stratification and clinical decision-making.

The survey by Bernhardt *et al.* presented primary care physicians with hypothetical DTC results reports indicating increased patient risk for Alzheimer's disease and glaucoma and average or reduced risk of Type 2 diabetes and cardiovascular disease. They found that 40% of physicians believed genomic testing can be helpful for clinical management, and 43% of respondents said that they would alter clinical management of a theoretical patient on the

basis of these genetic testing results [12]. Physicians' free-response comments to the survey suggested potential ways that genomic testing might affect clinical management, such as increasing disease-specific clinical exams like mental status or eye exams. With regard to diabetes and cardiovascular disease, respondents suggested that genomic test results might change the frequency of laboratory testing and could motivate them to counsel healthier lifestyles. In the specific survey scenario of average or decreased diabetes and cardiovascular disease risk, physicians notably did not anticipate using the low-risk genomic testing result to reduce screening frequency.

Similarly, in the survey by Powell *et al.*, 42% of respondents who were familiar with DTC tests felt that they could be useful for clinical care [15]. Among those who responded affirmatively about the benefit of DTC tests, approximately 80% said that they would use test results to screen at an earlier age and more frequently individuals at high genetic risk, although specific diseases were not enumerated in the survey. In the Mainous *et al.* survey of family practitioners, respondents reported greater utility for applying genomic testing to counsel patients about disease risk for breast cancer (94.9%) and hemochromatosis (74.9%) than for diabetes (25.2%), Alzheimer's disease (30.3%) or cardiovascular disease (25.4%) [17].

Taken together, recent physician surveys show reasonably positive attitudes regarding the value of genomic testing for clinical management generally and guiding screening initiation and frequency specifically. The dichotomization of diseases into categories for which genomic testing has greater or lesser potential benefit mirrors the distinction between diseases with single or few well-characterized disease-causing genetic variants and those for whom variation across the entire genome might contribute in some way to disease risk.

Motivating patient behavior change

A second way physicians might believe genomic testing to have clinical value is as a tool for counseling patients for health behavior change. However, Grant *et al.* found that only 23% of physicians surveyed believed that knowledge of a high genetic susceptibility to Type 2 diabetes would motivate patient behavior change. Similarly, Bernhardt *et al.* found in their survey addressing US primary care physician attitudes towards DTC genomic testing that only 10–15% of respondents who consider genomic testing potentially clinically useful would use the test results for diabetes and cardiovascular disease risk to counsel patient behavioral change. In contrast, among all survey respondents, approximately 45% reported that genomic testing would motivate patients to adopt healthier behaviors [12]. These results suggest that physicians may be skeptical about the ability of genomic risk information to motivate patients to change their dietary and physical activity habits to prevent chronic disease.

Unlike the potential application of genomic test results to risk stratification, the use of genomic testing for counseling patient behavior change has been evaluated in randomized clinical trials. For example, trials of genomic testing for Type 2 diabetes risk have not demonstrated improvements in patient health behaviors and outcomes [20–22]. In a systematic review of genetic testing for motivating a variety of behaviors, including

smoking cessation, dietary modification and increased physical activity, there was a measurable disparity between intention to change behavior based on genetic test results and actual behavior change [23]. These empiric findings seem to confirm the physician skepticism captured in surveys about the use of genomic testing to motivate patients. Behavior change has proven a challenging problem across many chronic illnesses, and the negative findings in initial trials of genomics for motivating lifestyle modification may indicate the need for more intensive counseling or assistance to achieve the desired behavioral transformation.

Drug selection

Pharmacogenetics, the use of genetic testing to guide drug treatment choices, may be the most anticipated application of so-called personalized medicine. In oncology, testing tumor pathology specimens – through either direct probing of DNA or RNA or through detection of gene products – has become increasingly important to target therapies to specific cancer-promoting mutations [24]. In recent years, many different tumor types have been sequenced, allowing the identification of the mutation spectrum of different cancers, raising the possibility of increasingly personalized chemotherapy [25]. For certain medications in more widespread use, common genetic variation is associated with efficacy or risk of adverse effects, either of which might be used to tailor drug therapy. For example, studies demonstrated wide variation in the dose of the anticoagulant warfarin needed to achieve therapeutic effect, depending on genetic variation at a few loci in the *VKORC1* gene that were differentially distributed across racial backgrounds, with potential implications for the safe initiation of the drug without risk of bleeding [26]. Similarly, GWAS have revealed a SNP in the *SLCO1B1* gene that increases one's risk of life-threatening muscle damage from treatment with simvastatin, a commonly prescribed medication for hypercholesterolemia [27]. Since these medications are for common conditions often managed by primary care physicians, pharmacogenetics may be the domain for which genomic testing has the greatest impact in widespread patient care. In 2009, Grant *et al.* found that approximately 50% of physician respondents would recommend a test to guide diabetes drug therapy for their patients, if available. Enthusiasm for pharmacogenetics might vary with its predicted purpose: Haga *et al.* found that, among primary care physicians surveyed, 78% reported that pharmacogenetic testing was 'Very important' to predict adverse response to treatment, whereas only 48% responded that testing was 'Very important' to predict treatment nonresponse [28].

Despite the general physician optimism about the application of genomic testing to drug therapy, the actual penetration of pharmacogenetic testing into clinical practice is difficult to assess. Stanek *et al.*, in a national survey of 10,300 generalists and specialists across nonsurgical and surgical fields, found that 98% of respondents felt that genetics could influence a patient's response to a medication, but only 13% of physicians had ordered a pharmacogenetic test in the 6 months prior to being surveyed [29]. Among physicians who had ordered a genetic test to guide drug therapy, however, Stanek *et al.* observed that comparable numbers of physicians reported prevention of drug toxicity (80%) and improving drug effectiveness (73%) as motivations for ordering tests [29].

Physicians have expressed a desire for clinical trial evidence or expert consensus regarding the application of pharmacogenomic testing. Grant *et al.* found that only 5–7% of physicians would be willing to order a pharmacogenetic test prior to clinical trial evidence demonstrating benefit. Similarly, Stanek *et al.* find that 72–80% of physician survey respondents reported that scientific publication, US FDA recommendation or expert guidelines were 'Important/Very Important' when considering ordering pharmacogenetic testing [29]. It seems, then, that physicians may perceive that genomic testing will be useful in optimizing drug therapy, but its uptake among generalists is limited at present. The application of pharmacogenomic testing to the initiation of warfarin therapy is one of the best studied and exemplifies some of the inherent challenges of pharmacogenomics, even before recent randomized trials called into question the benefit of genetic testing in this context [30–32]. Despite the presence of FDA guidelines issued in 2010 for the application of genetic testing for warfarin susceptibility prior to initiation of therapy, Bernhardt *et al.* found in their survey of primary care physicians that 89% of those physicians who had started a patient on warfarin had never ordered a genomic test prior to treatment initiation [12]. In fact, in a theoretical survey scenario, only 32% of respondents would use pharmacogenetic testing to guide initiation of warfarin therapy, despite 70% of respondents acknowledging its potential usefulness to guide treatment. The case of warfarin demonstrates that favorable attitudes toward genomic testing and translation into clinical practice are highly divergent. Furthermore, it suggests that expert guidelines, while cited as a potential barrier to uptake of genomic medicine [11], may be necessary but are not sufficient for generalized adoption of genomic medicine.

Physician perceptions of the limitations of genomic testing

Many barriers to genomic medicine may counterweight the potential clinical utility described above. Physician-level barriers will determine the rate of the adoption of genomic medicine and are multifaceted. Most important is the highly variable knowledge and comfort with genetic concepts broadly and their specific applications to clinical medicine, which have been reported in multiple studies [13,15,19,28–29,33–36]. For example, in a survey of US physicians including generalists and specialists, Selkirk *et al.* found that 79 and 69% of primary-care and nonprimary-care physicians, respectively, report that "lack of knowledge about genomic medicine" is a barrier to its incorporation in practice [36]. Similarly, Haga *et al.* found that, while only 43% of respondents to a survey of US primary care physicians reported inadequate knowledge of genomic testing, feeling well-informed about genomic testing was a very strong predictor of genomic test utilization (an odds ratio of 4.6 of ordering a genomic profile for a patient) [19]. These survey findings are reflective of the experiences, described by Manolio *et al.*, of leaders from several US genomic medicine centers who identified lack of understanding by clinicians among the barriers to adoption at those sites [37].

Studies have inconsistently identified an association between age or time since medical school graduation and familiarity with genetic testing. Klitzman *et al.* found no association between decade of medical school graduation (from 1960–1969 through 2010–present) and experience ordering genetic tests of any kind among internal medicine physicians (generalists and specialists) at two US academic medical centers [13]. However, Stanek *et*

al. found that the odds of using pharmacogenetic testing currently or within 6 months increased with each decade of age across surgical and nonsurgical generalists and specialists. Compared to those aged 20–39 years, physicians aged 40–49 years, 50–59 years, 60–69 years and 70 years or older had an odds ratio for adoption of pharmacogenetic testing of 1.41, 1.73, 2.16 and 2.62, respectively [29]. Similarly, Powell *et al.* found an odds ratio of 2.34 for awareness, perceived usefulness and preparedness to use DTC genetic testing comparing physicians 51 years old or older to those aged 41–50 years [15].

While the above studies examined self-reported familiarity or use of genetic or genomic testing, Baars and colleagues used a questionnaire to test directly respondent knowledge of traditional genetic concepts and technology (as opposed to more recent genomic approaches) among Dutch physicians. Limited genetic proficiency was prevalent across physician age categories and specialties, with general practitioners, gynecologists, and pediatricians scoring 64, 75 and 81% on a genetic knowledge assessment, compared with 95% for clinical geneticists [33]. Educational efforts, particularly focused on the practical aspects of genomic medicine, may find a willing audience among physicians across disciplines.

Another physician-level barrier to the adoption of genomic testing is the challenge of incorporating an additional data modality into an already time-strapped physician-patient encounter. Specifically, surveys have identified that physicians perceive the time needed to appropriately counsel patients about genomic testing to be a significant burden. Najafzadeh *et al.* conducted a focus group of Canadian physicians addressing the benefits and barriers of genomic testing. Among the physician-level themes highlighted by their participants was “Additional time pressures that personalized medicine will put on clinical practice” [34]. Similarly, among the themes highlighted by Arar *et al.* in their semistructured interviews with providers at a US Veterans Health Administration clinic were concerns about “Personnel and workload,” “Time and length of the visit” and “General workflow” [18]. Selkirk *et al.* found that 58% of physician respondents reported that the “Time required for patient education” was a barrier to adopting genomic testing [36].

The unclear clinical benefit of genomic medicine is another barrier to its adoption. Participants in the Najafzadeh focus group raised concerns about the lack of clinical guidelines for the use of genetic tests [34]. In a national survey of US primary care providers with price-reduced access to genomic testing through a DTC testing company, Haga *et al.* found that 60–70% of respondents reported that “Uncertain clinical utility” was a reason they had not ordered testing for their patients [19]. Similarly, several of the other surveys described here identify the absence of guidelines directing the appropriate use of genomic testing for both clinical management and drug selection as a barrier to use [13,29,36]. Again, the findings in surveys of physicians reflect those reported by Manolio *et al.* in their review of the experiences at several US genomic medicine centers, in which they describe “lack of clinician acceptance” and “limited evidence and conflicting interpretation of benefit/value” as barriers to adoption at those sites where genomic testing is available [37]. The perceived limitations of genomic testing and barriers to adoption identified in the studies described here clearly define areas of future research and interventions – physician education and clinical systems that facilitate reviewing genomic test results with patients, for example – that may yield increased uptake of genomic medicine.

It is important to note that barriers to implementing genomic medicine may be present at least two other levels besides physicians: health systems and patients [11]. Barriers to genomic medicine can also occur at the interface between these levels, such as in patient-physician communication or physician navigation of the genomic medicine infrastructure of their health systems. The genomic medicine community will need to address barriers at all levels for the successful clinical integration of genomics.

Conclusion

In the decade since the publication of the human genome, dramatic scientific and technologic progress has made personalized genomic medicine increasingly accessible. Genomic testing in clinical practice, however, remains limited. Physicians remain optimistic that genomic medicine will be increasingly used in the clinical context, in particular for guiding screening practices and for optimizing medication choice. Variability in knowledge and comfort with genomic technologies, as well as a relatively limited clinical trial supported evidence base or expert guidelines, are often cited reasons for the modest uptake of genomic testing in clinical practice. We suggest that an important aspect of future research into genomic medicine will be to focus concretely on how physicians use genomic data in the clinical context.

Future perspective

Several gaps in our understanding of how physicians might perceive and use genomic testing are amenable to study. The push to bring genomic technology to clinical medicine may be driven primarily by scientific and technological advances. Progress in the acquisition and analysis of genomic data has brought the promise of personalized medical care, but the agents of implementing genomic medicine at the bedside, physicians, have so far had a limited role in guiding that clinical implementation. While the studies reviewed here highlight a general optimism among physicians about the use and benefits of genomic medicine, particularly in the near future, the paucity of physicians who have actually ordered or have direct familiarity with genomic testing suggests that increasing physician exposure to genomic testing and understanding their responses to the capabilities of genomic technology is essential to capitalizing on their optimism. Numerous institutions have established genomic testing programs already, and unsurprisingly have faced many common challenges, at the patient, system and physician levels [37]. We propose several lines of inquiry that we feel would be fruitful over the next several years to better understand physicians' use of genomic medicine.

First, although not specifically examined in any of the surveys referenced here, the diversity of opinions on the possible uses of genomic data and the variable uptake of genomic testing in clinical care suggest that, even in circumstances when genomic information is available, it would be used in different ways by different providers. Recent work has focused on how patients use and respond to genomic data [38], and a more direct examination of how physicians use their patients' genomic information would be similarly revealing [39,40]. As guidelines are lacking for the use and interpretation of genomic data, studying how physicians actually use genomic data would more concretely inform the perceived

differential utility of specific forms of genomic data for clinical management, drug selection or counseling patient behavior. Recent studies have begun to address the real-life application of genomic data, including the technical aspects of the reliability of next-generation sequencing technology for clinical application, the challenges of identifying reportable findings, discussing sequencing results with patients and identifying how to support physicians [41,42]. Such studies move genomics out of theoretical survey space into an examination of actual clinical processes and will illuminate technical and interpretive aspects of the practical application of genomic data in the clinic.

Second, independent of how physicians use genomic data, it seems important to determine what, if any, gaps in current clinical care physicians might see as amenable to the implementation of genomic technology. What are the current challenges they face in clinical medicine for which genomic medicine may be a part of the solution? A similar approach has been suggested specifically for the application of genomics to cancer diagnosis, prognosis, and personalization of treatment [43]. It would be helpful to assess what interpretation or implementation aids, professional society guidelines or expert referrals would be most useful to physicians using genomic tools. Scientific progress and the increasing availability of genomic medicine have not yet been sufficient to penetrate clinical practice, suggesting, unsurprisingly, a need to understand a translational step that bridges scientific discovery and clinical care delivered by physicians. Most importantly, this type of implementation research is best done in the context of actual genomic data pertaining to actual patients. The barriers to the adoption of genomic medicine and high-yield points of intervention are likely to be most clearly revealed when examined in their clinical context rather than in the form of a hypothetical survey instrument.

Third, the findings of several of the surveys described here make clear that physicians do not use the results of genomic testing to guide clinical management even when they feel knowledgeable about genomic concepts, demonstrated in surveys addressing pharmacogenetic testing prior to warfarin initiation. That familiarity and even comfort with genomic medicine are inadequate for its appropriate application suggests other barriers to adopting this new technology in clinical practice. Unlike health systems-level barriers to genomic testing in clinical practice, the disregarding or misapplication of genomic testing when it is available suggests a limitation at the level of the physician that, if understood better, might be reversible. Further research into how practicing physicians actually use genomic testing might enable them to have a voice in the discussion of how best to use new genomic discovery to improve patient health and wellbeing.

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Executive Summary

- Genomic scientific discovery greatly exceeds clinical use of genomics
- Rapid recent progress in genomic technology and scientific discovery has not been matched by adoption of genomic testing by physicians in clinical practice.
- Physicians generally perceive genomic medicine as potentially useful
- Despite the slow uptake of genomic medicine in the clinical context, physicians generally believe genomic testing can be useful to clinical care, in 5–10 years if not at present.
- Perceived benefits of genomic medicine
- Physicians perceive genomic testing as useful for informing disease screening, drug optimization and avoidance of adverse drug effects, and, to a lesser extent, modifying patient behaviors.
- Perceived limitations of genomic medicine
- Physician knowledge of and familiarity with genomic technology as well as a desire for clinical evidence and expert guidelines are the primary physician-level barriers to clinician uptake of genomic medicine.
- Future research focused on physicians' use of genomic information needed
- We suggest that the next steps in the research of genomic medicine adoption focus on physicians and study their interaction with actual genomic data.