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COMMENTARY

Expanded carrier screening panels—does bigger mean better?

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Background on carrier screening

Prenatal carrier screening is offered for some inherited conditions based on recommendations of the American Congress of Obstetricians and Gynecologists (ACOG) and the American College of Medical Genetics and Genomics (ACMG). Currently, ACOG and ACMG recommend that cystic fibrosis carrier screening be offered to all women of reproductive age and that fragile X syndrome (FXS) carrier screening be offered to women with a family history suggestive of FXS or who ask to have testing following genetic counseling (Committee Opinion 469 2010; Committee Opinion 486 2011). For individuals of Eastern European Jewish descent, ACOG recommends carrier screening for Tay-Sachs disease, Canavan disease, cystic fibrosis, and familial dysautonomia (Committee Opinion 442 2009) stating that further testing should be permitted with appropriate counseling if the patient inquires about other conditions that occur more commonly in their ethnic group. ACMG recommends general population screening for spinal muscular atrophy, though this is unsupported by ACOG (Committee Opinion 432 2009; Prior 2008). All of these conditions are inherited in an autosomal recessive fashion except for fragile X syndrome, which is X-linked. People have two copies of each autosomal gene, one inherited from each parent. Recessive conditions manifest when both copies of the same gene have a mutation or do not function normally. Carriers have one abnormal gene copy, as well as one normal copy and are asymptomatic individuals. A 25 % risk for an affected child exists when both parents are carriers, as that poses a one in four risk for a child to receive a gene mutation from both parents. It is estimated that each individual is a carrier of between zero and seven severe childhood recessive conditions, with an average of 2.8 found in one study (Bell et al. 2011).

As the first condition for which ethnicity based carrier screening was offered, cystic fibrosis (CF) is the most common life-limiting autosomal recessive condition in non-Hispanic Caucasians. The debate over general population carrier screening began in 1990 following the discovery of the gene associated with cystic fibrosis (Karem et al. 1989; Beaudet 1990; Caskey et al. 1990; Tatsugawa et al. 1994). The discovery of the gene and the subsequent development of a genetic test were considered breakthroughs in science that would presumably lead to a cure. Questions of when and to who to offer the test presented a new ethical quandary at that time. The first report regarding routine CF carrier screening recommended against offering it to pregnant women stating that it should not *yet* be considered standard of care (Caskey et al. 1990). With the main benefit being to provide information for reproductive decision making, the potential limitations include anxiety over residual risk, anxiety associated with carrier status, and the cost of testing a large volume of people with very little financial benefit (Beaudet 1990). This debate was largely resolved over the next 10 years by an improvement in testing that increased detection rate, thereby reducing residual risk after negative CF carrier testing. By 2001, prenatal and preconception carrier screening for CF was

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implemented in routine obstetric practice to identify couples at risk of having a child with classic CF in the non-Hispanic white population (Committee Opinion 486 2011). The most recent ACOG recommendation advises that a 23 mutation panel, which has a detection rate of 88 % in the non-Hispanic white population, be offered to individuals of all ethnic backgrounds (Castellani et al. 2010; Committee Opinion 486 2011; Grody et al. 2001). In an effort to ascertain how this recommendation is being applied in clinical practice 10 years after the original recommendation was made, Darcy et al. (2011) surveyed a group of obstetricians throughout the USA and found that 12.3 % were unaware of screening guidelines, 17.7 % were unable to interpret testing results, 16.5 % experienced barriers to offering screening, and 43 % lacked information pertaining to carrier rates, screening sensitivity, and residual risk.

Advancements in reproductive technologies have paralleled the advancements in genetic testing. This has allowed the information gained through carrier screening to be applied in practical ways. While some individuals may desire to know carrier status for preparation purposes, some people may make actionable decisions based on genetic test results. Couples who are known carriers prior to conception now have the options to choose in vitro fertilization with preimplantation genetic diagnosis (PGD) or use of donor sperm or oocytes to prevent an affected pregnancy in addition to options of natural conception, adoption, and avoiding parenthood. There are some cultures in which changing the choice of partner may result from this type of information (Bach et al. 2007). For those who have already conceived but had carrier testing early in the pregnancy, prenatal diagnostic testing by chorionic villus sampling, or amniocentesis may be performed to identify affected pregnancies. If a pregnancy with CF is identified, the parents may then choose to terminate the pregnancy, make an adoption plan, or use the early diagnosis to emotionally and logistically prepare for a child with additional needs. While reproductive procedures carry a cost and potential for complications, they provide couples with information and options once they have learned their carrier statuses.

Expanded carrier screening

In this age of genomic medicine, genetic testing is becoming widely available at increasingly affordable costs. Many commercial companies are now offering expanded carrier screening panels for ethnicity based and general population carrier screening, but recommendations from the professional organizations to which we subscribe have not kept pace with their developments. Counsyl, whose mission is to "scale up the Jewish community's successful campaign of universal carrier screening for Tay-Sachs," has been offering a carrier panel of over 100 recessive diseases since 2008 (Levenson 2010; Srinivasan et al. 2010), and the cost of panel testing is often lower than carrier testing for CF alone. Such panels have created a new debate over how they should be utilized responsibly and effectively. Recommendations by ACOG regarding CF carrier screening include that the decision to have testing should be reached by informed choice and that patients should receive information about the condition and inheritance pattern before having testing (Committee Opinion 486 2011). Typically, when using a panel, patients do not have the opportunity to select which diseases they will receive results about nor do they understand the nature of every disease on the panel. Issues of decreased penetrance, variable expressivity, and current or potential disease treatment *or lack thereof* confound the process of informed consent.

No guidelines regarding the use of expanded carrier screening panels exist from ACOG or the National Society of Genetic Counselors. The Public and Professional Policy Committee of the European Society of Human Genetics published guidelines in 2011 regarding direct-to-consumer (DTC) genetic testing for common disorders for health-related purposes (ESHG 2010; van El et al. 2011). These guidelines suggest that poorly predictive tests may give rise to psychological harm. They additionally advise that if a test is capable of detecting high risks for serious conditions with implications for treatment or prevention then pre- and post-test genetic counseling is needed (ESHG 2010). Recently, ACMG published a professional statement pertaining to the issues that arise with expanded carrier screening; however, adherence is voluntary (Grody et al. 2013).

The new ACMG statement lists five criteria that conditions included on a genetic screening panel should meet : (1) The disorders should be of such a nature that most at risk patients would consider having prenatal diagnosis to facilitate reproductive decision making; (2) When adult-onset disorders are included, patients must provide consent to screen for these conditions, especially in instances where there may be implications for the individual or their family members; (3) For each condition, the causative genes, mutations, and mutation frequencies should be known in the population being tested so that residual risk for those that test negative can be correctly assessed; (4) There must be validated clinical association between the mutations detected and the severity of the disorder; and (5) Compliance with the ACMG Standards and Guidelines for Clinical Genetics Laboratories (Grody et al. 2013). Borry et al. (2011) similarly state that a preconception carrier test should maximize benefit and minimize risks, which is particularly difficult in the DTC setting. They assert that many concerns regarding DTC genetic testing can be addressed by involving a physician; however, "if these physicians are not well educated about which tests should be given based on specific criteria, they may simply become a pawn in the commercial companies' attempt at increasing their market size"

(Borry et al. 2011). Counsyl began as a DTC company but now accepts samples exclusively through ordering physicians.

The goal of carrier testing is to identify couples that are carriers of mutations in the same gene, and thus, at risk to have affected offspring. In 2012, Counsyl published the results of 23,453 clinical samples tested and this sample identified 127 carrier couples. In addition to identifying carriers, Counsyl also incidentally identified 78 individuals as homozygotes or compound heterozygotes for conditions on their panel, as can be seen in Table 1 (Lazarin et al. 2012). These are genotypically affected individuals who (most likely) had not previously come to medical attention. Although not without potential benefit, this can be an unanticipated consequence of carrier screening that may lead to psychosocial burden, unnecessary follow-up, and healthcare expenditure.

Such results serve as evidence that some conditions on the panel do not meet the criteria set forth by ACMG. Specifically, there are mutations on the panel that have unclear clinical significance, and therefore, have unclear implications in reproductive decision making (criteria 1 of the ACMG statement). Further evidence to restrict the number of mutations being tested and reported on preconception panel testing is presented by Bell et al. (2011). In their study, a next-generation sequencing (NGS) platform was used to screen several hundred DNA samples for 448 severe recessive diseases of childhood. They discovered that roughly 10 % of disease mutations in commonly used databases are incorrect. As NGS technology will likely be implemented in the future for not only carrier screening but also for newborn screening, they discuss that widespread application of such testing should not be rushed into without accurate data and appropriate resources for patients, including knowledgeable providers and accessible genetic counseling.

Table 1 Individuals identified as homozygous or compound heterozygotes and carrier couples for conditions on expanded carrier screening panel (Lazarin et al. 2012)

Condition	Number of compound heterozygotes/ homozygotes identified	Number of carrier couples identified
Alpha-1 antitrypsin deficiency	38	47
Cystic fibrosis	9	27
GJB2 related DFNB1 nonsyndromic hearing loss	6	5
Factor XI deficiency	5	3
Gaucher disease	4	2
Familial Mediterranean fever	3	5
Carnitine palmitoyltransferase II deficiency	2	1
Medium chain acyl-CoA dehydrogenase deficiency	2	1
Sickle cell disease	2	10
Short chain acyl-CoA dehydrogenase deficiency	2	1
Achromatopsia	1	
β-Thalassemia	1	2
Hexosaminidase A deficiency	1	
Familial dysautonomia	1	2
Lipoamide dehydrogenase deficiency	1	
Niemann-Pick disease type C	1	
Pompe disease	1	
Spinal muscular atrophy	1	15
Total	84	121

Several diseases included on expanded carrier panels may also have unclear implications for pregnancy and family planning. For example, conditions like MTHFR, achromatopsia, factor V Leiden thrombophilia, hemochromatosis, and short chain acyl-CoA dehydrogenase deficiency are all conditions with reduced penetrance and variable expressivity that are unlikely to be life-threatening in a patient with a negative family history. For such conditions, reproductive options like PGD with IVF are not automatically available or even allowed in some countries. Another controversial condition that is often found on expanded carrier screening panels is alpha-1 antitrypsin deficiency (AATD). AATD is the condition for which Counsyl has identified the largest number of carrier couples and largest number of homozygotes or compound heterozygotes (Lazarin et al. 2012). Of the 127 carrier couples identified in their clinical sample, 47 were for alpha-1 antitrypsin deficiency (Lazarin et al. 2012). Because of its reduced penetrance and uncertain clinical presentation in the newborn period and into adulthood, it does not meet the recently published ACMG criteria for panel test inclusion. General population AATD testing poses unique preconception and prenatal testing considerations and serves as a good example to study when considering the clinical implications of expanded carrier screening and evaluating which conditions should be included.

What is alpha-1 antitrypsin deficiency?

AATD is an inherited condition that can cause lung and liver disease of variable severity. AATD is interchangeably referred to as autosomal recessive and codominant, as both alleles independently produce alpha-1 antitrypsin (AAT), a protease inhibitor, in gene dependent concentrations. AAT is necessary in sufficient serum concentrations to bind to an enzyme that otherwise destroys healthy lung tissue. The most common AAT deficiency allele is PI*Z. Homozygotes for PI*Z have serum concentrations of AAT of less than 40 % of normal.

These classically affected individuals are at highest disease risk. Another common deficiency allele is PI*S, an intermediate disease allele which results in serum concentrations of AAT lower than normal but higher than that of PI*Z. Over 60 rarer AAT deficiency alleles have also been identified. While most AATD carriers remain healthy, carriers exposed to environmental risk modifiers such as smoking are more likely to develop related disease than genotypically normal individuals. People with classic AATD (PI*Z homozygotes) commonly develop pulmonary emphysema in the third to seventh decade of life, though age of onset is significantly related to environmental factors, such as smoking status (ATS/ERS Statement 2003). In non-smokers, pulmonary disease may not present until the sixth or later decades of life and lifespan can be normal. Some individuals may never develop symptoms even with the classic disease genotype (Stoller and Aboussouan 2012; ATS/ERS Statement 2003).

While emphysema is exclusively of adult-onset presentation, AAT is made primarily in the liver and abnormal accumulation can result in neonatal liver complications. For a small number of affected children, liver disease presents in infancy as jaundice, elevated liver enzymes, or serious disease. Approximately, 2.5 % of children with classic AATD (PI*ZZ) develop cirrhosis, requiring liver transplantation or resulting in death (ATS/ERS Statement 2003; Sveger 1976). AATD is the genetic condition for which pediatric liver transplantation is most frequently performed in the first year of life. A second peak for risk of liver disease occurs after age 35. Current research suggests that between 20 and 40 % of PI*ZZ individuals develop clinical liver disease in their lifetime (ATS/ERS Statement 2003; Teckman 2007). Extreme variability of AATD exists between and among families, and prediction of severity is not possible even when the genotype is known.

The other common AAT allele, PI*S, makes a protein that is recycled by the body faster and results in a serum level of AAT higher than that of the Z allele. While a PI*SZ individual has some pulmonary risks, S type AAT does not accumulate in the liver, and therefore, does not carry the same risk for liver damage (ATS/ERS Statement 2003). Individuals that are PI*SS do not have severely deficient serum levels of AAT and therefore do not have the same risk for pulmonary disease as PI*SZ or PI*ZZ (McGee et al. 2010). The Z allele originated in Scandinavia and roughly 2–3 % of Caucasians in North America are carriers. The S allele originated in the Iberian Peninsula, and about 3 % of North Americans are carriers (de Serres et al. 2010).

Accessible and accurate carrier testing for disorders like AATD prompts careful consideration of whether and how such testing should be implemented in preconception, prenatal, and general screening practice. AATD has a relatively high carrier rate, and counseling may be challenging because AATD is not a fully penetrant condition and clinical outcomes are difficult to predict. Multifactorial influences, modifier genes, and epigenetic factors are all suspected to alter disease presentation among those with deficiency alleles, though no modifiers aside from smoking have been specifically identified. While some genotypically affected individuals are asymptomatic, the disease can be serious, with an appreciable risk for childhood morbidity and mortality. Though specific outcomes cannot be predicted from genetic results, knowing AATD genotype may be important to some for family planning considerations and/or for lifestyle modification.

What are current recommendations for screening for AATD?

To determine when genetic testing for AATD is appropriate, the American Thoracic Society/European Respiratory Society (ATS/ERS) published guidelines in 2003 and categorized recommendations as type A, B, C, and D for specific populations (Table 2). In the reproductive setting, they make a type B recommendation. This means that an individual who has a high risk of having AATD-related diseases or whose partner is affected or is a carrier of AATD should discuss genetic testing with a genetics specialist, acknowledging that it could be reasonably accepted or declined. General population testing is not recommended by the current ATS/ERS guidelines (ATS/ERS Statement 2003). Furthermore, in relation to screening asymptomatic adults with no prior increased risk for AATD, they make a type D recommendation. This states that screening should not be performed due to concerns regarding psychological effects of testing asymptomatic individuals. Such psychological effects have been investigated in populations who have undergone CF carrier screening. Henneman et al. (2002) found that 7/17 carriers felt less healthy after receiving results; however, all identified carriers said that they would make the same decision to be tested again. Similarly, Lewis et al. (2012) found short-term negative effects (anxiety and guilt) among CF carriers but that the same participants experienced long-term "reproductive empowerment" stemming from the control they felt over the ability to

Table 2 Range of Recommendations by ATS/ERS for Genetic Testing (ATS/ERS Statement 2003)

Recommendation	Description
A	Testing is recommended.
B	Testing should be discussed, acknowledging that it could be reasonably accepted or declined.
C	Testing is not recommended (testing should not be encouraged).
D	It is recommended that testing not be performed (testing should be discouraged).

make informed decisions. Another potentially adverse effect of genetic testing is the fear of genetic discrimination if abnormal results are obtained. This concern has largely been addressed by the Genetic Information Non-discrimination Act of 2008 (Baruch et al. 2008).

The ATS/ERS guidelines only recommend that AATD testing be performed (a type A recommendation) for those who have symptoms consistent with AATD, which include emphysema or COPD in adults, unexplained liver disease in newborns, and siblings of adults and adolescents known to be affected. The rationale for early detection in these groups is to allow individuals to modify lifestyle and reduce risk for developing and/or worsening of symptoms.

In summary, AATD carrier screening for individuals with no related family history is unsupported by existing ATS/ERS guidelines and the disorder does not meet suggested ACMG criteria for carrier panel inclusion. In a distinct but related issue, the World Health Organization (WHO) does recommend neonatal screening for AATD based on potential medical advantages of detecting AATD at an early age and before smoking habits and occupations are established (Sveger and Thelin 2000). This WHO recommendation supports the idea of general population AATD screening but not discuss its utility as a preconception/prenatal test for the purpose of reproductive options.

In a family with no history of AATD, is preconception testing warranted?

Although several evidence-based guidelines specifically recommend against general population preconception AATD testing, test availability and affordability pushes clinicians to assess whether testing should be offered to patients and permitted to interested consumers. Primary worries fall into three broad categories: lack of adequate informed consent and follow-up, financial and psychosocial burden to participants who may never develop health consequences of their genes, and concern that reproductive decisions will be made regarding conditions with uncertain disease course. Those who do test positive as either heterozygous or homozygous for AATD may feel overwhelmed by this information. With no personal experience with the condition and the uncertainty of whether or not any symptoms will develop, genetic counseling is indicated for those facing personal or reproductive risk to assist them in processing and utilizing genetic information. In Israel, some conditions are tested for free of charge in an effort to reduce the incidence of affected individuals. This includes testing for Tay-Sachs disease and cystic fibrosis regardless of ethnic group and thalassemia major and familial dysautonomia based on ethnicity. Israeli laws require that prenatal primary caregivers inform patients of other available genetic tests based on family or personal history or ethnic group. In Israel, this includes AATD based on ethnicity. Disclosure of *all* carrier screening results must be accompanied by genetic counseling to ensure that implications of results and issues of residual risk are appropriately addressed (Rosner et al. 2009). Nearly half of US obstetricians surveyed in 2011 were unaware of genetic carrier frequencies, test sensitivities, and residual risks (Darcy et al. 2011).

An expanded carrier panel allows interested individuals to determine large quantities of personal genetic information, yet those undergoing an expanded panel may not be fully informed about each condition for which they receive testing or the implications of abnormal results. In practice, it is not feasible to inform patients of the nature of each condition tested, and for this reason, ACMG recommends a generic and general test consent form that is sufficient for pretest counseling (Grody et al. 2013). Most laboratories performing the testing only accept patient samples obtained through a medical provider; however, many healthcare providers themselves are unfamiliar with some conditions tested, issues of residual risk and actionability of information attained. In settings where expanded carrier panels are applied, adequate pre- and post-test counseling and follow-up are important to reduce negative outcomes.

As evidenced by AATD testing, it is possible that a test primarily designed to assess reproductive risk may inadvertently identify an asymptomatic individual with the disease. This poses potential ethical challenges to professionals (Jahnke et al. 2012) and may also pose an unanticipated psychosocial burden to patients who were unaware of this possible outcome of testing. In addition to the psychosocial burden, there is a burden to the healthcare system in general as each person identified through this method may undergo expensive baseline testing and follow-up that may have otherwise not been necessary. Those identified may or may not have wanted this type of information. While some patients may use their genetic results to improve lifestyle choices or to make medical management and informed reproductive decisions, other patients may view genetic predisposition as destiny or wish they had never undergone testing. Offering testing without providing appropriate pre- and post-test counseling is a potential disservice. Without mandated practice guidelines from professional membership organizations regarding panel tests at large, genetic counselors and other health care professionals may struggle with responsible implementation of expanded carrier panels in both specialty and general practice. Discussing proper pre- and post-test counseling and protocols is essential to responsible practice and appropriately advising patients regarding the possibility of unexpected outcomes may be an essential component of proper informed consent (Dondorp and de Wert 2013; van El et al. 2013).

By rationale of informed consent, any person or couple undergoing expanded carrier testing should be made aware of the implications of being a genetic carrier of each disease,

possibly identified as an asymptomatic homozygote, follow-up recommendations, and the availability of preimplantation and prenatal genetic diagnosis. Only after the process of informed consent can patients knowledgeably evaluate the personal utility of expanded carrier screening and make an informed choice about pursuing testing.

Implementation of expanded carrier screening in genetic counseling practice

While expanded carrier screening panels may foster professional issues regarding implementation and conditions tested, there are both public and professional interests in using the available tests as they are, no doubt, powerful tools. Whether such panels are routinely offered in screening practice is currently at the discretion of each practitioner; however, when consumers request to test, the genetic counseling profession should support their decision and strive to provide adequate pre- and post-test services. Ultimately, research on outcomes of expanded carrier testing is needed to clarify the risks and benefits.

So, is bigger better?

Should the maximum possible number of genetic carrier tests be simultaneously performed on a patient sample if the cost to the patient is not increased? It is hard to deny an intrinsic appeal to this approach, where the most possible information is obtained with minimal (or equivalent) input of resources. Yet, due to the quantity, nature, and variability of conditions on such panels, this approach stands in contrast to historical and current recommendations for genetic carrier testing. Thus, these authors conclude that bigger, for the sake of being bigger, is not better.

Carrier screening has traditionally only been offered in cases where the condition is severe, phenotype and genotype correlations are clearly delineated, and there are resources available to prevent the birth of a child with that condition. The recent ACMG position statement accordingly states that the selection of disorders to test for (in the absence of a family history for the disorder) should be decided upon using set criteria rather than by including as many as are feasible (Grody et al. 2013). They recommend that complete and transparent information be provided about conditions with mild phenotypes, variable expression, low penetrance, and/or characterized by an adult and that patients should have the ability to opt out of these results (Grody et al. 2013). Of note, Counsyl and some other commercial entities offering panel testing do allow customization of testing panels.

Alpha-1 antitrypsin is often mild, certainly variable, incompletely penetrant, and most often of adult-onset. In accordance with ATS/ERS and ACMG testing guidelines, these authors conclude that AATD does not presently belong on any testing that may be offered as general population preconception or prenatal screening. Similar conclusions may be drawn for other conditions on expanded carrier panels. The benefits and limitations of individual disease carrier testing and panel carrier screening are important areas for further research.

As genetic and genomic testing capabilities rapidly advance, ethical issues will likely become increasingly apparent. The European Society of Genetics recently discussed that the time has come for practitioners to prepare for the future of medicine in which personal genomics are key (Dondorp and de Wert 2013; Van El et al. 2013). Both patients and healthcare providers have had to deal with ambiguous results before, and in some ways, genetic results are no different (Evans 2011). When people receive unexpected or unpleasant results from other types of medical testing results must be dealt with accordingly. The aftermath of test results is not always uniformly positive but should yield to medical benefit. In this light, the issue surrounding carrier testing is primarily deduced to whether information obtained is useful in reproductive decision making. For AATD, specifically, no evidence supports that reproductive choices may be altered or affected births prevented. Reduction of births affected with serious diseases that are costly to treat may result in large-scale healthcare savings and justify up-front cost of general population carrier screening. For conditions where reproductive decisions are largely unaltered due to reduced penetrance and/or mild disease course, the expenditure of healthcare resources on carrier testing may be less advantageous. The economic impact of general population expanded carrier screening is an important issue for further and separate consideration.

Other newer clinically available genomic tests, including whole exome sequencing (WES), also pose risks of significant incidental findings. Addressing this issue for WES specifically, ACMG states that if there is medically actionable information detected through testing, then the patient must be informed of incidental findings. The essence of this statement supports the idea of early disease detection using genomic methods. By this rationale and current WHO recommendations, AATD testing may be appropriate in general population newborn screening for the purpose of improving medical outcomes rather than for the purpose of reproductive decision making. This issue should also be separately explored.

Ready or not, the era of genomic medicine is upon us, presenting healthcare professionals with both challenges and opportunities. As availability of genetic testing panels' increases, the need for genetic counseling services is also anticipated to increase. Trained and practiced in informing and consenting patients, providing anticipatory guidance, delivering genetic results, and supporting patients; through decision making and medical management, genetic counselors are

likely to be an invaluable resource to other healthcare providers and patients alike. Rather than resist inevitable change, genetic counselors as a profession should strive to clarify appropriate uses and counseling strategies for expanded carrier panels. This may be accomplished in part through ongoing dialogue and exploration of benefits and limitations to patient populations. As other healthcare providers and commercial laboratories may independently offer testing, it may be prudent for genetic counselors to prepare for a new market of patients with limited pretest knowledge whose first encounter with a genetic counselor occurs only after abnormal results are obtained on an expanded carrier panel.

In a field that never stagnates, with ever-evolving genetic technologies, genetics professionals are familiar with the line—however fine at times—between what is clinically possible and what is clinically beneficial. Genetic testing advancements usher opportunity for genetics providers to strategically market and utilize a unique skill set. Staying abreast of emerging challenges remains essential for professional growth and optimal service delivery. It thus falls upon those immersed in the field to responsibly engage in the new genomic era and serve as leaders in the face of uncertainty. Fortunately, genetics professions have historically grown through change and by both experience and training professionals possess the fundamental knowledge necessary to navigate this journey—wherever it may lead.

Compliance with ethics guidelines All research done in the development of this article complied with the current laws of the USA.

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