What are Genetic Services, an Overview

Genetics refers to many aspects of health promotion and disease prevention. It can refer to inborn variation in susceptibility to disease, and to disorders that are passed on in families. It includes complex conditions such as cancer, heart disease, and diabetes, where genetic and non-genetic factors play a role in the development of a disorder. Genetics embraces birth defects and their causes, such as chromosomal disorders, neural tube defects, and fetal alcohol syndrome. Medical genetics has four major areas of specialization: the study of chromosomes (cytogenetics), the study of the structure of DNA (molecular), the function of genes (biochemical), and the medical application to diagnosis and patient care (clinical genetics). The benefits of clinical genetics and genetic testing (molecular, biochemical and cytogenetics) are in their infancy and hold great promise for the prevention of morbidity and mortality, as well as for more targeted medical management than is now possible.

Clinical Genetics

Clinical genetics began as a small sub-specialty field of pediatrics dealing with dysmorphology, the diagnosis of children with unusual features or syndromes. With the development of chromosome studies, geneticists were often consulted about whether such expensive chromosome studies should be performed. With the technological advances and decreased costs of genetic testing and screening, the consultative role of the geneticist expanded to interpretation of results, the management of rare disorders, and the continued role as detective to determine diagnoses in complex cases. Today, the practice of clinical genetics is a family-oriented care approach that provides a range of services throughout the lifecycle aimed at health education, management, prevention, and integration with primary care and sub-specialty care. Genetics is unique in that it deals with health issues for an individual and their family. This branch of medicine is committed to providing the necessary resources to communicate effectively with families about their genetic risks, especially through the utilization of genetic counselors. A board certified or board eligible genetic counselor is a health professional with a specialized graduate degree in medical genetics and counseling. The American Board of Genetic Counseling provides certification for this profession. A genetic counselor is well trained to provide information and support to families who have members with birth defects or genetic disorders and to families who may be at risk for a variety of inherited conditions. Counseling services include identification of families at risk, investigation of problems present in the family, interpretation of information about a disorder, assessment of inheritance patterns, communication of risks, and review of available options and services (*Career* 1).[6] The genetic clinical service team approach provides essential medical, laboratory, and counseling services to diagnose and manage complex disorders.

[6] *Career Information…*

Clinical Genetic Services Identifies Lethal Genetic Condition in 12-Year-Old Boy

A 12-year-old boy came to the OU Medical Center-Children's Hospital for removal of metal plates used in repair of pectus excavatum, a depression of the chest. The surgery had been performed three years previously; however, the mother had failed to have the plate surgically removed at the appropriate time. After surgical removal of the plate, the surgeon requested a consultation with Genetics to determine if this tall thin young man had the genetic disorder Marfan syndrome. There is not a genetic blood test for the disorder, therefore a geneticist must rely on clinical experience and coordinate the multi-disciplinary diagnostic workup. The genetics team evaluated the child; however, the physical exam and family history were impeded due to surgical pain and the child's current placement in foster care. Although the family history was sparse it was reported that his mother was of above average stature and two half-brothers were also tall. The child was unable to tolerate the typical physical examination required for diagnosis of Marfan syndrome; however, the limited physical examination was suggestive of the condition. The geneticist then ordered the routine work-up to rule-out Marfan syndrome that includes consultations with ophthalmology and cardiology. Those appointments were scheduled to follow a few weeks after discharge from the hospital. However, the geneticist insisted the cardiology consult and echocardiogram be performed prior to discharge due to some respiratory symptoms and the distance the center was from their home. The cardiology consultation was performed and the echocardiogram revealed a massively dilated aorta of 6.7 cm. This could result in sudden death with exercise or activity. Repair was scheduled and surgery performed. The child had a post-surgical stroke and required physical therapy, and he is expected to fully recover. The ophthalmology evaluation was negative for signs diagnostic of Marfan syndrome. Further detailed physical examination did support the diagnosis of that condition and preventive health strategies to prevent cardiac collapse and family support information were provided. However, the story does not end there. With genetics you have to treat the whole family. The two half-brothers were examined and, although tall, were not diagnosed with Marfan syndrome.

Marfan syndrome is a heritable disorder of the connective tissue that affects many organ systems, including the skeleton, lungs, eyes, heart and blood vessels. This condition affects 1 in 5,000 men and women of any race or ethnic group. A person with Marfan syndrome may be at severe risk of sudden death unless they are diagnosed and obtain proper treatment because the aorta may dissect without warning (National Marfan 1).[42]

[42] *National Marfan Foundation...*

Providers in genetics are called geneticists who have received board certification in clinical and laboratory genetic services. Their professional degree may be a MD, DO, PhD or masters. Before obtaining board certification, genetic professionals must meet a certain criteria in relation to their position in the genetic field (Wisconsin State Department of Health 8-9):[56]

Clinical Geneticists - physicians with training in a primary specialty, such as pediatrics, obstetrics, internal medicine, and who have additional subspecialty training in the clinical aspects of genetics

Clinical Biochemical Geneticist - specialists in the diagnosis and treatment of inborn errors of metabolism

Clinical Molecular Geneticists - experts in the use of molecular (DNA) tools in the diagnosis of genetic processes

Clinical Cytogeneticists - experts in the utilization and interpretation of chromosome analyses

Ph.D. Geneticists - scientists with clinical training to handle complex scientific issues in clinical genetics

Genetic Counselors - masters-level degree with training in all aspects of medical and clinical genetics as well as in counseling

American Board of Obstetrics and Gynecology, Division of Maternal and Fetal Medicine provides certification for:

Maternal Fetal Medicine Providers - physicians with training in a primary specialty of obstetrics and additional subspecialty training in the clinical aspects of prenatal/obstetrical genetic care

In addition, genetic services may be provided by other health care providers, such as nurses with advanced training in genetics.

[56] *Genetics Services Plan for Wiscon…*

What Makes Genetic Testing Different?

Prediction: Traditional medical tests inform about the patient's present condition, while genetic tests "inform" about a possible future condition.

Information beyond the patient: Genetic tests affect other individuals who have not chosen to undergo testing.

Genetic Testing

Many genetic disorders can be identified by a blood test. The three types of genetic blood tests include molecular, biochemical, and cytogenetics. Molecular (DNA) testing is the newest and most sophisticated of genetic testing and it involves the direct examination of the DNA molecule itself and is the focus of the Human Genome Project. Molecular testing can provide information about a particular DNA sequence or the presence or absence of a particular gene. Biochemical genetic testing focuses on gene products such as enzymes and other proteins. Cytogenetic testing looks at the number and characteristics of chromosomes. Genetic tests serve as useful tools, and medical practitioners might request genetic testing for the following reasons:

- To perform pre-implantation genetic diagnosis for the selection of healthy embryos for implantation
- To confirm a diagnosis of an existing condition
- To conduct prenatal testing
- To screen newborns
- To identify carriers of genetic mutations
- To perform **presymptomatic** testing (predictive for a disorder)
- To perform **predisposition** testing (inform about a possible future condition)

Tests for adult-onset disorders like breast cancer (predisposition) and Huntington disease (presymptomatic) already are widely used, and state public health programs screen newborns for a variety of genetic diseases such as phenylketonuria (PKU) and sickle cell disease. However, these applications only hint at the potential of genetic testing technology (Johnson 1).[26] Technological advances in genetic testing will allow providers to identify patients at risk for the leading causes of death in America (e.g., cancer and heart disease) and provide information on opportunities to decrease those risks. A doctor will be able to order genetic testing to determine the most effective and least toxic drug therapy. Improving drug therapy is an important aspect of genomics research since "more than 100,000 people die each year from adverse responses to medications that are beneficial to others" (Casey 2).[7]

Genetic testing opportunities are exciting and hold great promise in health promotion. A critical component of genetic testing is genetic counseling. Genetic testing must be offered and performed in an ethical and informed environment where the implications of testing, limitations of the testing, and the results of testing are communicated accurately and in a non-directive manner so that people can make informed health decisions.

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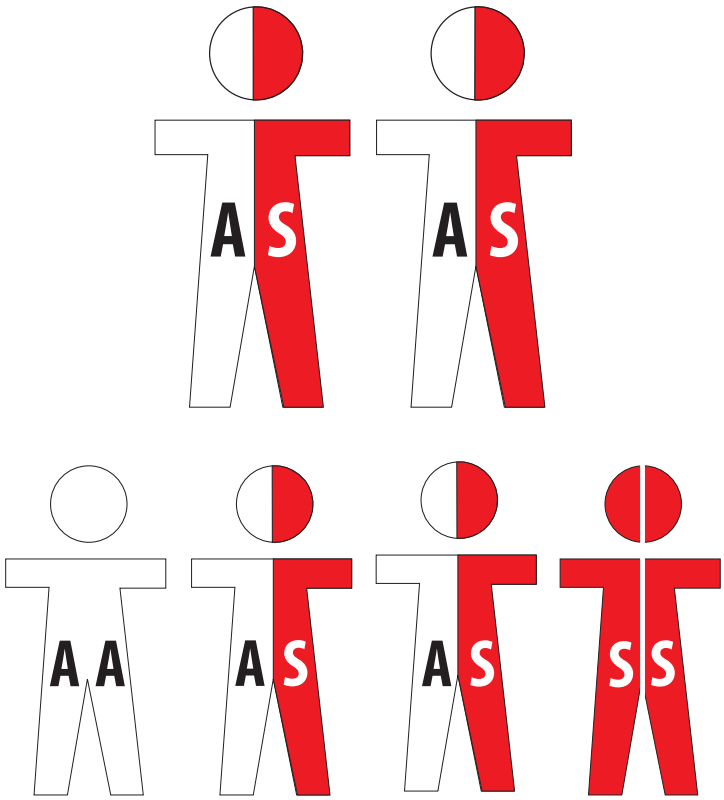
[26] *Johnson, Alissa...*

[7] *Casey, Denise K...*

Genetic Testing may be Useful and Necessary Throughout the Lifecycle

Preconception/prenatal: In the 1970s, screening women during the first trimester of pregnancy for neural tube birth defects by testing maternal serum for alpha feto-protein was begun, and the same technology was later shown to screen for infants with Down syndrome and other genetic disorders. Screening couples prior to pregnancy to identify carrier status for autosomal recessive genetic disorders began in the 1970s for Tay Sachs disease and sickle cell anemia. Such testing detects if a person carries a gene for a genetic disorder, but is not affected. In 2001, the American College of Obstetricians and Gynecologists (ACOG) recommended DNA screening for cystic fibrosis, an autosomal recessive disorder, to all couples seeking preconception or prenatal care. Tay Sachs disease, sickle cell anemia, and cystic fibrosis are disorders that occur in offspring of parents who are both carriers of an abnormal gene. Screening couples for carrier status allows them to make informed decisions about future reproduction. For example, if one parent is a carrier and the other is not, then their children are not at risk for a disorder. If both parents are carriers, then there is a 1 in 4 chance with each pregnancy to have a child with the disorder (autosomal recessive inheritance). Identification of disorders preconceptionally or during pregnancy through genetic testing will only increase and provide significant opportunities to prevent morbidity and mortality.



Autosomal Recessive Inheritance - Sickle Cell Anemia (Hemoglobin SS Disease)

Both parents have sickle cell trait (hemoglobin AS). They each possess one gene for normal hemoglobin (A) and one gene for sickle hemoglobin (S). Since both parents are a carrier for sickle cell trait, there is a risk for having a child with sickle cell disease (hemoglobin SS Disease). With each pregnancy there is a 25% chance that their child will have normal hemoglobin (AA), 50% chance of having sickle cell trait (AS) and 25% risk of having sickle cell anemia (SS). This risk applies to each pregnancy. There is a 1 in 4 (25%) chance of having a child with Sickle Cell Anemia (Hemoglobin SS Disease).

Newborn: Screening newborns for genetic disorders began in the 1960s, with PKU testing, and continues to be a highly successful program to prevent mental retardation. Today there are over 30 disorders for which newborns can be screened by a simple heel stick, and the future predicts the technical feasibility of screening each infant for over 1000 disorders.

Pediatric: In the newborn nursery major malformations and metabolic emergencies often warrant clinical evaluation and subsequent genetic testing. Older children may warrant genetic testing for minor malformations, subtle metabolic conditions, and growth and development delay. For adolescents, abnormal puberty and reproductive health may result in genetic testing.

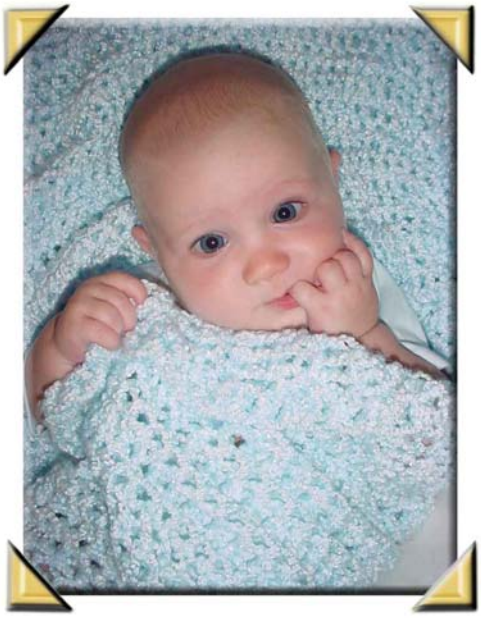
Adult: Adult presymptomatic testing for the autosomal recessive iron overload disorder, hemochromatosis, the autosomal dominant disorder of Huntington disease (HD), and tests for genetic predisposition for breast and colorectal cancers are a few examples of genetic testing in the adult. HD is often thought of when discussing adult genetics. HD is a devastating, degenerative brain disorder for which there is, at present, no effective treatment or cure. HD slowly diminishes a person's ability to walk, think, talk and reason, until he or she becomes totally dependent upon others for care, and profoundly affects the lives of entire families emotionally, socially and economically. Huntington disease is an autosomal dominant disorder with complete penetrance. This means each child of an affected person has a 50-50 chance of inheriting the gene and everyone who inherits the gene will develop the disease (*What Is* 1).[55] Huntington disease gene testing is an excellent example of the need for sensitivity and competency that must be provided when testing for genetic disorders. Implications for the individual and their family must be considered before the test is performed. Inadequate genetic counseling in the testing process for Huntington disease can result in profound consequences for the person and their family. There have been reports of healthy individuals committing suicide when they discover they have the gene for Huntington disease. These are complex counseling issues that must be considered before a genetic test is administered. Breast cancer gene testing is an example of predisposition testing. Unlike the gene testing for Huntington disease, an abnormal test result does not indicate disease or predict the inevitability that a disease will occur; it carries a risk of being affected, but does not indicate a certainty. For example, some people identified with the changed gene for breast cancer will never manifest breast cancer. Breast cancer gene testing leads to similar complex genetic counseling issues. A woman will need to consider what she will do if her test results are positive for the gene *BRCA1* or *BRCA2*, the genes linked to breast cancer. If the result is positive, what preventive measures will the woman elect to pursue? Will she elect to have a prophylactic mastectomy, or chemoprevention and increased surveillance of the breast? Will she share the test results with other at-risk family members?

[55] *What Is Huntington's...*

Genetic testing is different than traditional testing and therefore should always include a before and after genetic counseling session. During a conference meeting for the Secretary's Advisory Committee on Genetic Testing in May 2002, Dr. David Mallott noted that a patient's traditional experience with medical testing is that testing will reveal "truths" about a health condition. This perception assumes testing will provide a definite yes or no answer about a possible disorder or condition. A genetic test rarely provides yes or no answers, and typically a test result is communicated in risk. Board certified or board eligible genetic counselors have been trained to communicate such risk effectively in a non-directive manner. In addition, the person undergoing testing should understand the implications to their family. Genetic testing goes beyond the individual being tested and consideration of how that information will or will not be communicated to other family members is an important component of the counseling session. National standards on who should provide genetic counseling services have yet to be determined, but competent genetic counseling services are an important component. Studies indicate that genetic counselors are essential in the provision of comprehensive genetic services. One study reported that high-risk obstetrical patients receiving evaluation and counseling from a genetic counselor improved the detection of identifiable genetic risk factors (Koscica et al. 1033).[32] Traditionally, and as this study reports, certified genetic counselors are best prepared to communicate risk. However, there are only 2,000 genetic counselors in the U.S., and just two (2) board certified genetic counselors are currently practicing in Oklahoma. It is important that standards for genetic counseling are developed, so that Oklahomans who receive genetic services receive appropriate non-directive counseling.

Genetic Clinical and Laboratory Services in Oklahoma

Oklahoma genetic clinical and laboratory services are primarily provided in Oklahoma City and Tulsa. The two genetic centers that provide clinical, laboratory (biochemical, molecular, and cytogenetic), and genetic counseling services are the OU Medical Center in Oklahoma City and HA Chapman Institute of Medical Genetics in Tulsa and Oklahoma City branch. As of September 16, 2002, Oklahoma has five M.D. board certified geneticists who provide clinical genetic services and four genetic counselors (two board certified). Prenatal genetic services are usually provided by maternal fetal medicine providers, board certified by the American Board of Obstetrics and Gynecology, Division of Maternal Fetal Medicine. Oklahoma has nine maternal fetal medicine physicians located in Oklahoma City and Tulsa.



[32] *Assessing Genetic Risk…*