PIK3CA gene
phosphatidylinositol-4,5-bisphosphate 3-kinase catalytic subunit alpha

Normal Function

The PIK3CA gene provides instructions for making the p110 alpha (p110α) protein, which is one piece (subunit) of an enzyme called phosphatidylinositol 3-kinase (PI3K). The p110α protein is called the catalytic subunit because it performs the action of PI3K, while the other subunit (produced by a different gene) regulates the enzyme’s activity. Like other kinases, PI3K adds a cluster of oxygen and phosphorus atoms (a phosphate group) to other proteins through a process called phosphorylation. PI3K phosphorylates certain signaling molecules, which triggers a series of additional reactions that transmit chemical signals within cells. PI3K signaling is important for many cell activities, including cell growth and division (proliferation), movement (migration) of cells, production of new proteins, transport of materials within cells, and cell survival. Studies suggest that PI3K signaling may be involved in the regulation of several hormones and may play a role in the maturation of fat cells (adipocytes).

Health Conditions Related to Genetic Changes

Klippel-Trenaunay syndrome

At least five mutations in the PIK3CA gene have been found to cause Klippel-Trenaunay syndrome. This condition is characterized by a red birthmark called a port-wine stain, abnormal overgrowth of soft tissues (such as skin and muscles) and bones, and vein malformations. The PIK3CA gene mutations associated with this condition arise randomly in one cell during the early stages of development before birth. These changes, which are called somatic mutations, are not inherited. As cells continue to divide during development, cells arising from the first abnormal cell will have the mutation, and other cells will not. This mixture of cells with and without a genetic mutation is known as mosaicism.

The PIK3CA gene mutations associated with Klippel-Trenaunay syndrome change single protein building blocks (amino acids) in the p110α protein. These changes lead to production of an altered p110α subunit that makes PI3K abnormally active. The altered enzyme triggers unregulated chemical signaling in cells, which allows cells to grow and divide continuously. Increased cell proliferation leads to abnormal growth of the bones, soft tissues, and blood vessels. Despite the involvement of PIK3CA gene mutations in cancer (described below) and the overgrowth of cells caused by changes in this gene, individuals with Klippel-Trenaunay syndrome do not appear to have an elevated risk of developing cancer.
Megalencephaly-capillary malformation syndrome

At least 15 mutations in the \textit{PIK3CA} gene have been found to cause a condition known as megalencephaly-capillary malformation syndrome (MCAP), which is characterized by overgrowth of the brain (megalencephaly) and abnormalities caused by enlargement of small blood vessels in the skin (capillary malformations). The mutations that cause MCAP overlap with those that cause Klippel-Trenaunay syndrome (described above). These mutations are not inherited from a parent; they arise randomly in one cell during the early stages of development before birth and lead to mosaicism. The presence of the mutation in different tissues helps explain why multiple conditions can be caused by the same gene mutations.

Most \textit{PIK3CA} gene mutations involved in MCAP change single amino acids in the \textit{p110$\alpha$} protein. These mutations lead to the production of an altered \textit{p110$\alpha$} subunit that makes PI3K abnormally active. The resulting unregulated signaling allows cells to grow and divide continuously. Increased cell proliferation in the brain and other tissues and organs leads to the overgrowth characteristic of MCAP.

Despite the involvement of the \textit{PIK3CA} gene mutations in many cancers (described below) and the overgrowth of cells caused by changes in this gene, individuals with MCAP do not appear to have an elevated risk of developing cancer.

Bladder cancer

Somatic mutations in the \textit{PIK3CA} gene have been found in some cases of bladder cancer. Bladder cancer is a disease in which certain cells in the bladder become abnormal and multiply uncontrollably to form a tumor. Bladder cancer may cause blood in the urine, pain during urination, frequent urination, the feeling of needing to urinate without being able to, or lower back pain.

Bladder cancer is generally divided into two types, non-muscle invasive bladder cancer (NMIBC) and muscle-invasive bladder cancer (MIBC), based on where in the bladder the tumor is located. A \textit{PIK3CA} gene mutation has been found in about half of NMIBC tumors. These mutations change single amino acids in the \textit{p110$\alpha$} protein. The altered \textit{p110$\alpha$} subunit appears to allow PI3K to become overactive. The increased signaling by PI3K likely contributes to uncontrolled cell growth and division and the formation of bladder cancer.

Epidermal nevus

Mutations in the \textit{PIK3CA} gene have been found in up to a quarter of people with a certain type of epidermal nevus (plural: nevi). Specifically, \textit{PIK3CA} gene mutations are associated with some keratinocytic epidermal nevi, which are abnormal skin growths that are composed of skin cells called keratinocytes. \textit{PIK3CA} gene mutations have not been found in other types of epidermal nevi.
The most common PIK3CA gene mutation found in epidermal nevi replaces the amino acid glutamic acid with the amino acid glycine at position 545 of the p110α protein (written as Glu545Gly or E545G). Studies suggest that this mutation causes cells to grow and divide more than normal. The resulting overgrowth of skin cells leads to formation of epidermal nevi. The genetic changes associated with this condition are somatic mutations and are present only in the cells of the nevus.

Despite the involvement of PIK3CA gene mutations in many cancers (described above) and the overgrowth of cells caused by changes in this gene, individuals with an epidermal nevus do not appear to have an elevated risk of developing cancer.

Head and neck squamous cell carcinoma

Lung cancer

Ovarian cancer

Cancers

Somatic mutations in the PIK3CA gene are found in many other types of cancer, including cancer of the ovary, breast, lung, brain, and stomach. These mutations are also involved in cancer of the colon (large intestine) and rectum, which are collectively referred to as colorectal cancer. These mutations change single amino acids in the p110α protein. Two common mutations occur in the same region and change the amino acid glutamate at position 542 or at position 545 of the p110α protein to the amino acid lysine (written as Glu542Lys and Glu545Lys, respectively). Two other common mutations occur in another region, changing the amino acid histidine at position 1047 of p110α to the amino acid arginine or leucine (written as His1047Arg and His1047Leu, respectively).

Cancer-associated PIK3CA gene mutations result in production of an altered p110α subunit that allows PI3K to signal without regulation. The increased signaling can contribute to an uncontrolled proliferation of cells, leading to the development of cancer. However, PIK3CA gene mutations may not cause cancer by themselves. Researchers suspect that some cases of cancer likely result from a combination of mutations in PIK3CA and mutations in other genes that influence cancer risk.

Other disorders

Mutations in the PIK3CA gene, including those found in some cancers, have been found to cause several other conditions related to overgrowth of tissues. These conditions include hemimegalencephaly; fibroadipose hyperplasia; and a condition called congenital lipomatous overgrowth, vascular malformations, epidermal nevi, and skeletal or spinal abnormalities (CLOVES) syndrome. Hemimegalencephaly is characterized by enlargement of one side of the brain and can cause seizures and
intellectual disability. Fibroadipose hyperplasia causes overgrowth of fibrous and fatty (adipose) tissues in various regions of the body, which leads to enlargement of different portions of the body, such as the lower body, an individual arm or leg, or one or more fingers or toes. CLOVES syndrome has multiple features, including an overgrowth of adipose tissue in the abdomen that is often associated with a reddish birthmark on the skin over it, in addition to blood vessel, skin, and bone abnormalities. It is unknown whether individuals with these disorders have an elevated risk of developing cancer.

As in Klippel-Trenaunay syndrome, MCAP, and epidermal nevus (each described above), the genetic changes involved in these disorders occur early in development and are found in only some of the body's cells. This mosaicism helps explain why different conditions involving different parts of the body can be caused by the same gene mutations. Together, the overgrowth disorders caused by PIK3CA gene mutations are known as the PIK3CA-related overgrowth spectrum (PROS).

**Chromosomal Location**

Cytogenetic Location: 3q26.32, which is the long (q) arm of chromosome 3 at position 26.32

Molecular Location: base pairs 179,148,114 to 179,240,093 on chromosome 3 (Homo sapiens Updated Annotation Release 109.20200228, GRCh38.p13) (NCBI)

Credit: Genome Decoration Page/NCBI

**Other Names for This Gene**

- p110-alpha
- phosphatidylinositol 3-kinase, catalytic, 110-KD, alpha
- phosphatidylinositol 3-kinase, catalytic, alpha polypeptide
- phosphatidylinositol-4,5-bisphosphate 3-kinase 110 kDa catalytic subunit alpha
- phosphatidylinositol 4,5-bisphosphate 3-kinase catalytic subunit alpha isoform
- phosphatidylinositol-4,5-bisphosphate 3-kinase, catalytic subunit alpha
- phosphoinositide-3-kinase, catalytic, alpha polypeptide
- PI3-kinase p110 subunit alpha
• PI3K
• PI3K-alpha
• PK3CA_HUMAN
• ptdIns-3-kinase subunit p110-alpha
• serine/threonine protein kinase PIK3CA

Additional Information & Resources

Educational Resources
• Molecular Biology of the Cell (fourth edition, 2002): PI3-Kinase Produces Inositol Phospholipid Docking Sites in the Plasma Membrane
  https://www.ncbi.nlm.nih.gov/books/NBK26822/#_A2861_

Clinical Information from GeneReviews
• PIK3CA-Related Segmental Overgrowth
  https://www.ncbi.nlm.nih.gov/books/NBK153722

Scientific Articles on PubMed
• PubMed
  https://www.ncbi.nlm.nih.gov/pubmed?term=%28PIK3CA%5BTI%5D%29+AND+%28%28Genes%5BMH%5D%29+OR+%28Genetic+Phenomena%5BMH%5D%29+AND+english%5Bla%5D+AND+human%5Bmh%5D+AND+%22last+360+days%22+AND+human%5Bmh%5D+AND+english%5Bla%5D+AND+human%5Bmh%5D+AND+%22last+360+days%22+AND+human%5Bmh%5D

Catalog of Genes and Diseases from OMIM
• CONGENITAL LIPOMATOUS OVERGROWTH, VASCULAR MALFORMATIONS, AND EPIDERMAL NEVI
  http://omim.org/entry/612918
• PHOSPHATIDYLINOSITOL 3-KINASE, CATALYTIC, ALPHA
  http://omim.org/entry/171834

Research Resources
• Atlas of Genetics and Cytogenetics in Oncology and Haematology
  http://atlasgeneticsoncology.org/Genes/PIK3CAID415ch3q26.html
• ClinVar
  https://www.ncbi.nlm.nih.gov/clinvar?term=PIK3CA%5Bgene%5D
• HGNC Gene Symbol Report
• Monarch Initiative
  https://monarchinitiative.org/gene/NCBIGene:5290
• NCBI Gene

• UniProt
https://www.uniprot.org/uniprot/P42336

Sources for This Summary


Citation on PubMed: https://www.ncbi.nlm.nih.gov/pubmed/23946963
• OMIM: PHOSPHATIDYLINOSITOL 3-KINASE, CATALYTIC, ALPHA http://omim.org/entry/171834
Citation on PubMed: https://www.ncbi.nlm.nih.gov/pubmed/22729224
Free article on PubMed Central: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3408813/
Citation on PubMed: https://www.ncbi.nlm.nih.gov/pubmed/30096301
Free article on PubMed Central: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6297116/
Citation on PubMed: https://www.ncbi.nlm.nih.gov/pubmed/26268729
Citation on PubMed: https://www.ncbi.nlm.nih.gov/pubmed/18794883
Free article on PubMed Central: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2757120/
Citation on PubMed: https://www.ncbi.nlm.nih.gov/pubmed/20009532
Free article on PubMed Central: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2835815/