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Opinion Article

Role of Fusion Genes in Cancer, Mechanism and its Therapeutic Implications

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DESCRIPTION

Fusion genes are unique genetic entities formed by the abnormal joining or fusion of two separate genes that originally reside at different chromosomal loci. This structural alteration can arise due to various genomic rearrangements, such as translocations, deletions, inversions, or duplications. Fusion genes have garnered immense attention in molecular biology and clinical research due to their involvement in cancer development, as well as their potential as diagnostic and therapeutic targets [1-3].

Mechanisms of fusion gene formation

Chromosomal rearrangements: Fusion genes are often a consequence of chromosomal rearrangements, where segments of chromosomes break and reattach to different chromosomes or positions. These rearrangements can juxtapose two genes, resulting in a hybrid gene transcript.

Types of fusion genes

There are different types of fusion genes, including:

Translocation-based fusions: Occur when segments of two chromosomes break and swap places, leading to the fusion of genes from different chromosomes.

Intrachromosomal rearrangements: Involve rearrangements within the same chromosome, leading to fusion genes composed of sequences from different parts of the same chromosome.

Intergenic fusions: Can involve the fusion of non-coding regions or regulatory elements from different genes, affecting gene expression or regulation [4,5].

Role of fusion genes in cancer

Oncogenic fusion genes: Fusion genes are frequently found in various cancers and are often oncogenic, driving cancer development by creating chimeric proteins that possess altered or enhanced functions. These proteins can disrupt normal cellular processes, promote uncontrolled growth, or inhibit programmed cell death.

Notable examples of fusion genes in cancer include:

BCR-ABL in Chronic Myeloid Leukemia (CML): Arises from the fusion of the Breakpoint Cluster Region protein (BCR) and Abelson Murine Leukemia (ABL) genes, resulting in a constitutively active tyrosine kinase, driving CML progression.

Eml4-Alk in Non-Small Cell Lung Cancer (NSCLC): Fusion between the Echinoderm Microtubule-associated protein-like 4 (EML4) and Anaplastic Lymphoma Kinase (ALK) genes, leading to an oncogenic kinase promoting NSCLC.

***TMPRSS2-ERG* in prostate cancer:** Fusion between the Transmembrane Protease Serine-2 (TMPRSS2) and ETS-Related Genes (ERG), affecting androgen-regulated transcription, implicated in prostate cancer development.

Detection and diagnostic significance

Molecular techniques for fusion gene detection: Various molecular techniques, including Fluorescence *In Situ* Hybridization (FISH), Polymerase Chain Reaction (PCR), RNA sequencing (RNA-seq), and microarray-based assays, are used to detect and identify fusion genes. These methods play a crucial role in cancer diagnosis, prognostication, and treatment selection.

Diagnostic and prognostic biomarkers: Fusion genes serve as important diagnostic and prognostic biomarkers in cancer. They aid in classifying tumors into distinct subtypes, guiding treatment decisions, and predicting patient outcomes [6,7].

Therapeutic implications

Targeted therapies: Fusion genes have become attractive targets for precision medicine and targeted therapies. Drugs specifically designed to inhibit or disrupt the aberrant function of fusion proteins have shown promise in treating cancers driven by these genetic alterations.

However, challenges exist in developing targeted therapies against fusion genes, including resistance mechanisms, off-target effects, and the need for continuous monitoring due to potential treatment resistance or relapse.

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The significance of fusion genes extends beyond cancer, with implications in various diseases, developmental disorders, and even normal cellular functions. Studying fusion genes provides insights into gene regulation, cellular signaling, and developmental processes.

Fusion genes represent an intriguing aspect of genomic alterations, playing a significant role in cancer development, diagnosis, and treatment. Their discovery has transformed our understanding of oncogenesis and paved the way for targeted therapies in cancer treatment. As research progresses, the identification and characterization of fusion genes continue to offer insights into disease mechanisms, personalized medicine, and therapeutic innovations, holding promise for improved patient care and outcomes in various clinical settings [8-10].

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